Silviculture Treatments for Ecosystem Management in the Sayward (STEMS): Establishment Report for STEMS 1, Snowden Demonstration Forest

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Silviculture Treatments for Ecosystem Management in the Sayward (STEMS): Establishment Report for STEMS 1, Snowden Demonstration Forest

Louise de Montigny

BRITISH COLUMBIA

Ministry of Forests Forest Science Program

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PREFACE

This technical report constitutes the establishment report for B.C. Ministry of Forests Experimental Project (EP) 1213, "Silviculture Treatments for Ecosystem Management in the Sayward (STEMS)." The intent is to preserve details of the procedures used and the data collected for researchers and forestry practitioners who will use and interpret the results of this study.

STEMS is a replication of the "Silvicultural Options for Harvesting Douglas-fir Young-Growth Production Forests" in the Capitol Forest near Olympia, Washington. The project was developed jointly by the managers of the Washington State Department of Natural Resources and the scientists of the Pacific Northwest Research Station. The experiment is designed to provide statistically valid comparisons of five stand treatments (clearcut, retained overstory, small patch cuts, group selection, and commercial thinning).

The decision to replicate the treatments in the Sayward Forest was based on the similarity of knowledge gaps in the Sayward Forest and the Capitol Forest. Both need sound quantitative information about how alternative practices affect the associated biological and ecological effects, the economic costs and returns, and the public response to visual appearance.

Agreement between the B.C. Ministry of Forests and the U.S. Department of Agriculture (USDA) Forest Service Pacific Northwest Research Station to share data and results will ensure that the statistical power of the overall experiment is greatly enhanced and the extrapolation over a wide geographic region can be done confidently.

For further information on the status of these projects, the reader should visit the STEMS website http://www.for.gov.bc.ca/hre/stems or the website for Silvicultural Options for Harvesting Douglas-fir Young-Growth Production Forests http://www.fs.fed.us/pnw/olympia/silv/wsonstud.htm.

The data files on which this report is based are archived at the B.C. Ministry of Forests Research Branch, under the supervision of the Branch Data Custodian.

ABSTRACT

Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of seven silvicultural regimes replicated at three sites in the Sayward Forest.

The STEMS experiment uses silvicultural systems and treatments to create diversity in forest structure that results in a variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure) to enhance biodiversity and wildlife. The STEMS experiment examines seven different treatment regimes, namely:

- Extended Rotation (non-treatment control)
- Extended Rotation with Commercial Thinning
- Uniform Dispersed Retention
- Aggregate Retention
- Group Selection
- Modified Patch Cuts
- Clearcut with Reserves

These silvicultural regimes create a range of gap sizes and frequencies that emulate natural variation in forest structure.

STEMS is a replication of the "Silvicultural Options for Harvesting Douglas-fir Young-Growth Production Forests" in the Capitol Forest near Olympia, Washington, developed jointly by the managers of the Washington State Department of Natural Resources and the scientists of the Pacific Northwest Research Station. The decision to replicate the treatments in the Sayward Forest was based on the similarity of knowledge gaps in the Sayward Forest and the Capitol Forest and because replication in Washington and British Columbia results in greater statistical power and ability to extrapolate over a wide geographic area.

This technical report describes the establishment of the first replication of STEMS in 2001 in the Snowden Demonstration Forest. Ongoing studies include:

- Tree growth and stand development, including understory vegetation
- Regeneration and light availability
- Windthrow, mortality, and coarse woody debris recruitment
- Harvesting production and impacts of residual tree damage and soil disturbance (in partnership with the Forest Engineering and Research Institute of Canada [FERIC])
- Visual quality and public response

The results of this experiment will be used to improve forest management and policies because results can be directly interpreted operationally due to the large-scale, replicated experimental design. The information will be especially relevant for forests with multiple use objectives.

ACKNOWLEDGEMENTS

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Thank you to researchers Eric Phillips and Craig Evans of FERIC, who provided the advice, assistance, and analysis of the harvesting study, to Jacques Marc of Forest Practices Branch for initiating the public perception study, and to Steve Mitchell and Robin Scott for their participation in the windthrow study. Many thanks to Robert Curtis and Dave Marshall of the USDA Forest Service Pacific Northwest Research Station for their patience in providing advice throughout the initiation and establishment of the project. Thanks also to Jim Peltarri of R. White Woods Ltd., whose talents and experience in the field contributed to the success of the plot layout and to the high-quality measurements. The photograph shown on the front cover was taken by Charlie Cornfield; photos in Figures 4–9 were taken by Zbigniew Olak; all others were taken by the author.

I would also like to thank everyone who contributed to the production of this technical report, especially Paul Nystedt and Rick Scharf of Research Branch. Thank you to reviewers Wendy Bergerud, Rob Brockley, and Rick Eriksen of the B.C. Ministry of Forests and Robert Curtis of the USDA Forest Service, Pacific Northwest Research Station.

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Clearcutting has been the primary silvicultural system applied on the coast over the last century and we have become very skilled at timber management on many types of terrain in varying climates. However, with increasing public demand for forests with multiple uses, including timber, recreation, non-timber forest products, and diverse wildlife habitat, clearcutting has become increasingly socially unacceptable. The forest industry is increasingly using alternatives to clearcut harvesting, but there is currently a lack of reliable scientific data to support decision-making regarding the use of alternative harvesting practices. Existing research studies have addressed various components of differing partial cutting systems, mostly in old-growth stands. However, no examples are available on the coast of silvicultural systems in second-growth stands, other than clearcutting, that have been systematically applied over an extended period of time and area, and that have the data collection necessary to make sound quantitative comparisons of their biological, financial, and social results.

The Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) project is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of seven treatments replicated at three sites in the Sayward Forest. The treatments include five different silvicultural systems: clearcut, patch cut, group selection, aggregate retention, and uniform dispersed retention, which are compared against two extended rotation options, with and without commercial thinning.

This technical report describes the establishment of the first replication in the Snowden Demonstration Forest. The results of this experiment will be used to improve environmental management and policies because results can be directly interpreted operationally due to the large-scale, replicated experimental design. The information will be especially relevant for forests with high multiple-use demands.

1.1 The Sayward Forest

The Sayward Forest, also known as the Sayward Landscape Unit or "the Sayward," exemplifies the increasing multiple-use demands on forest resources. The Sayward Landscape Unit (LU) covers 112 000 ha in the Campbell River Forest District. Over the past century, logging or fire has disturbed most forests in the Sayward, such that 63% of the area consists primarily of second-growth forests between 40 and 80 years old. The few old-growth stands remaining are fragmented and primarily at higher elevations. The Sayward has an extremely valuable recreation resource, with a large concentration of lakes, karst/cave areas, and significant scenic values. Along with three provincial parks, the Sayward includes 67 Forest Service recreation sites, and numerous hiking and mountain biking trails. The Sayward also features important wildlife habitats, cultural and heritage resources, mineral values, a source of domestic water, and a source of non-timber forest products such as salal, mushrooms, and berries. With a 20–50% predicted rise in population on eastern Vancouver Island (Rose 2002), the demand for resources in the Sayward is expected to increase dramatically in the next decade .

The Vancouver Island Land Use Plan and the Sayward Landscape Unit Plan have identified the importance of the multiple resource use in the Sayward and characterized the area as a General Management Zone. The overall

goal is to promote timber harvesting and production in accordance with principles of integrated resource management that consider all resource values, with stewardship guided by the principle of sustainable use. Ecosystem management techniques can be used to achieve these goals.

1.2 Ecosystem Management

Ecosystem management applies ecosystem-ecology concepts to managing forests, fully recognizing the complex interactions between biotic and abiotic components and ecosystem processes and resulting patterns. Therefore, sustainable ecosystem management should consider the natural patterns of forest structure and dynamics. Systematically fostering a balanced distribution in time and space of many stand conditions and stages of stand development can sustain diverse, multiple values in specific forest landscapes (DeBell and Curtis 1993).

Silviculture can be used to create gap sizes and frequencies that emulate the variation in forest structure and openness among different site types and ecological zones. The Sayward Forest is classified as a Natural Disturbance Type 2 (B.C. Ministry of Forests, 1995), generally characterized as having infrequent fires of moderate size (20–1000 ha) occurring about every 200 years as the primary stand-initiating event. The natural forest landscapes would therefore be dominated by roughly even-aged stands greater than 20 hectares, less than 200 years old, with pockets of unburned, old-seral stands greater than 200 years. Within the fire-affected areas, stand ages would vary from younger to older. Older stands would likely exhibit canopy mortality, especially from root rot, a process that would correspond with small gaps and understory reintiation (Oliver and Larson, 1990).

In traditional silviculture terminology, creating small gaps is equivalent to group selection involving the removal of three to 10 stems. Small group selection would provide regeneration opportunities similar to those within intact forests and maintain an uneven age structure with trees of varying age, height, and diameter distributed patchily in a fine-grained mosaic. However, Douglas-fir does not successfully regenerate and reach the canopy in gaps less than about 700–1000 m^2 in the Coastal Western Hemlock Zone (Franklin and Dyrness 1973) because light levels may be too low. Also, Douglas-fir germinants prefer organic seedbeds (Minore 1979). For this reason, larger gaps and soil disturbance should be created to specifically regenerate Douglas-fir.

Modifying conventional silvicultural practices and additional measures can actively enhance stand characteristics favourable to some biodiversity, wildlife, and aesthetic goals (Curtis et al. 1998). These include:

- modified thinning practices to develop mixed-species stands, multiple canopy layers, and more diverse understories. Irregular thinning and underplanting of openings with tolerant species can be used to promote vertical and horizontal heterogeneity
- thinning, especially if begun early, to produce large trees with deep crowns and a more open environment for understory development. Early thinning minimizes the duration of the least diverse and least productive (for wildlife) stem exclusion stage of stand development
- retention of some hardwoods and minor species in thinning to enhance species and structural diversity
- protection or retention of standing dead and downed trees, where feasible, for nest sites and coarse woody debris
- protection of live trees with cavities as nest sites

- creation of snags, cavity trees, and downed trees in stands where they are scarce or absent
- use of extended rotations (in combination with thinning) and alternative regeneration systems to develop a wide range of stand ages, tree sizes, and structures

To maintain the range of old-growth–like habitats at the stand level requires the continuing presence of large-diameter snags and downed logs (Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995). Windthrow should be included as part of the management strategy to leave downed woody debris.

Maintaining a range of stand structures across a landscape provides consistent employment in silvicultural operations and in the use, manufacture, and remanufacture of wood products. Retaining diverse stand structures across the landscape also offers a sustained supply of various forest values—low-quality timber products from thinnings, high-quality timber products from harvesting previously thinned forests (which simultaneously produce habitat in the stand-initiation stage before trees regrow), and other forest values such as recreation, mushrooms, scenery, floral greens, and berries. Non-timber forest products will probably never produce as much revenue as timber provincially; however, they can be economical at the local level, thereby increasing employment diversity and making certain silvicultural practices, such as thinning and pruning, more economically attractive (Oliver 1992).

The STEMS experiment uses many of these silvicultural treatments for ecosystem management. Details of each treatment regime are discussed in Section 4, Prescribed Treatments. The results of this experiment will be applicable to coastal regions and other areas of the province, especially areas that are at the urban interface and are visually sensitive. These treatments could also be used in areas of high recreation use, critical wildlife habitats, unstable terrain, community watersheds, or areas where maintaining a high degree of stand-level biodiversity is desirable.

1.3 Silviculture Options for Harvesting Young-growth Production Forests

The first replication of STEMS is part of a larger study that includes three replications of the same six treatments (excluding the aggregate retention treatment) in the Capitol Forest near Olympia, Washington. This study is officially titled "Silviculture Options for Harvesting Young-growth Production Forests," but, for simplicity, will be referred to here as the Capitol Forest Project. The decision to replicate the treatments in the Sayward Forest was based on the similarity of knowledge gaps in the Sayward Forest and the Capitol Forest. Both need sound quantitative information about how alternative practices affect the associated biological and ecological effects, the economic costs and returns, and the public response to visual appearance. The British Columbia study added the aggregated retention treatment for comparison with other treatments because of its increasing use in coastal British Columbia.

The Capitol Forest Project is a collaborative study between the U.S. Department of Agriculture (USDA) Forest Service Pacific Northwest Research Station and the Washington Department of Natural Resources in the 90 000-acre Capitol Forest. The experiment is intended to compare silvicultural regimes having long-term value for both research and demonstration.

The following design considerations, based on the work of Curtis et al. (2004), were important in the decision to replicate the experiment in the Sayward Forest:

1. **Joint design by managers and scientists** Local managers and field foresters identified the driving issues and developed harvesting options that reconcile aesthetic values with economic return and sustained wood production in visually sensitive areas. Research scientists guided the experimental design. Together, they developed rational options (silvicultural systems), ways to implement and test them, and methods to obtain the quantitative data needed for useful comparisons.

2. **Operational and adaptive nature** Operational scale and feasibility were essential if the project was to provide useful information to managers and be effective as demonstration areas. Therefore, for each option, any intermediate operations necessary to provide the desired regeneration and stand structure will be implemented. Thus, a given treatment might be necessary on some options or sites, but not on others; the associated costs and complications become part of the evaluation.

3. **Financial and staffing resources** No special funding was available to either organization. Stand treatments are done as part of an ongoing operation within the timber sale program of the Washington Department of Natural Resources. Remeasurements were planned so that basic data could be collected within the framework of existing funding levels for the USDA Forest Service Pacific Northwest Research Station.

4. **Continuity** Any project comparing silvicultural systems must continue beyond the careers of the initial participants, who incorporated features that favour long-term survival and continuity.
   a. A wide range of options: Social needs and desires change, as do forest conditions. Even in multi-purpose forests, the relative importance of different values will likely differ 20 or more years hence.
   b. Large treatment areas and adequate replication: Size and number of treatment areas must be sufficient to accommodate the damage and mortality that are to be expected on any operation unit, and still give useful information. Larger areas are generally required for assessments of non-timber values such as wildlife habitat than for timber values alone.
   c. Applicability to major portions of the forest land base: The areas selected must represent major portions of the land base available for multi-purpose forestry.
   d. Minimum essential expenses: Essential expenses must be minimized so that the project can survive the lows of financial cycles and political interest. The project should be flexible enough to accommodate additional work when resources permit.
   e. Multiple disciplines and organizations: Inclusion of multiple disciplines and cooperating organizations can increase cost-efficiency and permit more comprehensive evaluations. Diversity in partners can help to buffer the project from the cycles of support that occur within and among disciplines and organizations.

A Memorandum of Understanding between the B.C. Ministry of Forests and the USDA Forest Service has been established to facilitate data sharing, and develop future related studies and sharing of results through joint meetings, workshops, and publications. In this way, the statistical power of the overall experiment is greatly enhanced and the extrapolation over wide geographic regions can be done confidently.

2.1 Goals and Objectives

The STEMS experiment is a rigorously designed, replicated, long-term silvicultural systems experiment that tests seven treatments: extended rotation (non-treatment control), extended rotation with commercial thinning, aggregate and uniform dispersed retention systems, group selection and modified patch cut systems, and a 10-ha clearcut with reserves. The seven treatments will be replicated at three sites. The first replication (STEMS 1) was established in the Snowden Demonstration Forest and harvested through the Small Business Forest Enterprise Program in 2001. The second site will be established near Elk Bay and harvested by Interfor in 2004. The third site will be harvested by B.C. Timber Sales in 2007. The STEMS experiment will help to determine how best to meet the goals and targets set out in the Vancouver Island and Sayward Landscape Unit Plans for multiple-use objectives.

The overall goals of the STEMS project are, within mature second-growth Douglas-fir stands:

- to create replicated examples of alternative harvest practices and silvicultural regimes that can be used as a demonstration area by foresters and planners in ecosystem management
- to provide quantitative information for evaluation of feasibility and costs of alternative regimes and of their long-term effects on production of timber volumes and values and other non-timber values
- to evaluate the effectiveness of contrasting silvicultural systems in reducing environmental and visual impacts of forestry operations, while supplying high timber outputs over time.

The STEMS project has both scientific and extension objectives:

1. **Scientific**
   a. quantitatively compare forest productivity, including residual trees, regenerating trees, understory vegetation, light environments, mortality and windthrow, and coarse woody debris, under contrasting silvicultural systems over an extended time period
   b. quantitatively compare timber outputs, production costs, and operational factors associated with harvesting, including post-harvest residual tree damage, soil disturbance and compaction, and slash loading
   c. quantitatively compare the public response to the various silvicultural treatments
2. **Extension**
   a. create three replicated examples of five silvicultural systems and two extended rotation treatments that can be used as demonstration areas by foresters and planners in ecosystem management and as experimental areas for scientists studying ecosystem dynamics
   b. facilitate the interpretation of forest management implications and the application of seven silvicultural systems or extended rotation treatments by providing current information about the biological, economic, and social results of the STEMS project to all interested audiences in a timely and appropriate manner

The results of this experiment will be applicable to coastal regions and other areas of the province, especially areas that are at the urban interface and are visually sensitive. These treatments could also be used in areas of high recreation use, critical wildlife habitats, unstable terrain, community watersheds, or areas where maintaining a high degree of stand-level biodiversity is desirable.

2.2 Experimental Design

The study is a randomized complete block design having seven treatments and a minimum of three replicates in the Sayward. There are another three replicates in the Capitol Forest in Washington (excluding the aggregate retention treatment), and other replicates could be established in the Pacific Northwest. Stand growth and yield information is based on repeated measurements on a grid of permanent plots, maintained for the life of the experiment. Supplementary short-term studies of harvesting costs and visual impacts are being done in cooperation with other organizations.

In STEMS 1, each of the seven treatment regimes was randomly assigned to one of seven treatment areas, which are the basic experimental units. The minimum acceptable area required for each treatment unit varies with treatment, being less for those that produce homogeneous stand conditions (10-ha clearcut) than for those that result in patches or sparse distribution of residual trees (35 ha for the patch cut).

Using large operational units as treatment areas is the only way to understand forest dynamics (Franklin 1989) and has several important advantages over using small research plots:

1. it is easier to generalize management results to the watershed and landscape because the experimental units accurately represent the spatial variation
2. direct observation of the treatment on the landscape can determine visual acceptance
3. there is a demonstration that the management treatments are both economical and feasible to implement because, by definition, they are operational

Although a series of smaller, short-term projects may seem more economical, they typically can study only one or two factors, and the process mechanisms are out of context. Also, they are not conducive to a long-term study in which causal links can be determined between a manipulated variable and some measured response (Monserud 2002). The STEMS project is multi-agency and interdisciplinary; its statistical design will ensure long-term opportunities for research that address land management issues and ecosystem productivity.

Note: This section covers only the Forest Productivity portion of the STEMS project. Two other aspects of the study, the Cost and Productivity Study (Evans et al. 2003) and the Public Perception Study (Marc 2005, in progress), are not discussed in this report.

2.3 Sampling Design

The overall sampling scheme consists of periodically remeasured fixed-area tagged tree plots located on a permanently monumented systematic grid within each treatment unit (an operational block). Spacing, number, and arrangement of plots depend on area and expected post-treatment stand heterogeneity. Any wildlife reserve patches, riparian strips, major road

rights-of-way, and inclusions of site or stand conditions that were markedly different from those on other units were excluded from the sample. Plot locations were established after major roads had been located, to minimize subsequent loss of plots (see Appendix 5).

Sample size was based on the expected post-treatment (not pre-treatment) stand structure condition. Treatments resulting in even-aged stand structures would require fewer samples than those resulting in multiple-age structures. The objective is to achieve about equal precision in estimates of means in all treatments, combined with precision as high as can be obtained at acceptable cost. The following 142 permanent growth and yield plots were established.

- Block 1 – Aggregate Retention: 26
- Block 2 – Extended Rotation with Commercial Thinning: 16
- Block 3 – Uniform Dispersed Retention: 21
- Block 4 – Clearcut with Reserves: 15
- Block 5 – Modified Patch Cuts: 27
- Block 6 – Extended Rotation (non-treatment control): 17
- Block 7 – Group Selection: 20

To avoid having two or more cohorts of very different numbers and diameters in several of the treatments, the plots were designed as multiple, circular, concentric fixed-area plots. A single fixed-area plot would sample an adequate number of small trees but an inadequate number of large trees, or an adequate number of large trees but an extremely large number of small trees. The choice of a basic 0.1-ha plot is based on the expectation that we will want to classify plot estimates by strata (patch vs. intervening area) in the modified patch cut and group selection treatments, which will require relatively small plots. The plot sizes, the size of tree measured in each, and the corresponding plot expansion factor are listed in Table 1.

Plots for regeneration and vegetation assessments are 3.99 m radius (0.005 ha) and are located on each cardinal point 17.8 m from the permanent plot centre.

Coarse woody debris (CWD) plots are measured by line intersect sampling (LIS) using 75-m line transects in a spoke pattern (3- to 25-m lines) established at the centre of each growth and yield permanent sample plot. The direction of the first 25-m transect is randomly chosen and the other two 25-m transects are established at 120° from each other.

TABLE 1 *Size of circular concentric fixed-area plots, size of tree measured in each, and the corresponding plot expansion factor*

Plot size (ha)	Plot radius (m)	Plot expansion factor	dbh of trees measured
0.01	5.7	100	>4.0 cm + ingrowth
0.05	12.6	20	>15.0 cm + ongrowth
0.10	17.8	10	>25.0 cm + ongrowth

2.4 Proposed Analysis

The randomized block design has seven treatments and a minimum of three replications (blocks). Note that the term "block" for the purposes of this discussion means the entire replication, such as the Snowden Demonstration Forest (throughout this manuscript, the term "block" is also used as an operational term for the treatment unit). The analysis is based on the averages of the plots within the treatment units. The ANOVA is therefore:

Source	Degrees of freedom	Error term
Block (B)	2	—
Treatment (T)	6	B×T
Error (B×T)	12	—
Total	20	

For the growth and yield study, the variable of interest is cumulative volume (and value) production over one rotation (or an equivalent time period since initial treatment in the case of the group selection and variable size openings). Although this is far in the future, the experiment is designed to allow such an analysis.

Intermediate results of interest will be comparisons of cumulative volume (and value) growth and mortality losses over successive time periods since establishment of the experiment. Short-term results suitable for early analysis will include:

- regeneration (natural and planted) establishment and development
- effect of treatments on shrub competition
- extent of logging damage to the residual stand
- effect of canopy opening sizes on regeneration establishment, composition, and growth.

Repeated measures analysis will be used to compare trends over time across treatments. If we regard the clearcut as the standard of comparison for regeneration, then Dunnett's test provides meaningful comparisons of the clearcut versus each treatment. Contrasts can be used to compare group selection versus patch cuts, green tree retention with aggregate retention, and extended rotation with commercial thinning and without. We could also regard the extended rotation without commercial thinning as the standard of comparison for residual trees. When conducting these specific comparisons, Bonferroni correction or other methods would be used to control the overall Type I error rate.

No advance information is available on the variability to be expected in this study, and so we cannot estimate the magnitude of differences detectable at a given significance level. Although three replicates is the minimum acceptable number of replicates, conclusions would be greatly strengthened with more replicates. Because of limited replications, unavoidable differences in initial stand conditions, and sampling errors involved, this experiment is inherently insensitive. We cannot expect to detect small differences. These installations have both demonstration and research functions, and, from the standpoint of practical application, differences in growth and yield must be large before they become the decisive factor in management decisions. Thus, results should still be useful even though the confidence limits may be wide. However, the data-sharing agreement with the USDA Forest Service Pacific

Northwest Research Station for the replications at the Capitol Forest will improve the sensitivity and narrow the confidence limits.

The use of multiple concentric fixed-area plots will maintain flexibility in methods for later analysis. However, note that, as regeneration develops and numerous small and medium-sized trees appear, failure to pick up these "ongrowth" trees will become a source of errors. These *must* be identified, tagged, measured, and properly coded at the measurement at which they first pass the applicable diameter limit. This merits a brief discussion on how to deal with ongrowth, as discussed by Curtis et al. (1996). If ongrowth trees are included in volume and growth computations for a given period, we introduce inconsistencies between successive values, because they are based on different samples. The effect may be negligible when averaged over a unit. We should preserve the option of calculating growth either as (1) differences between successive plot estimates including ongrowth, or (2) differences between successive plot estimates based on trees present at the start of the growth period only. The latter procedure is recommended by Dilworth and Bell (1972, p. 47). For option 1, plot expansion factors used, identified by tree size (Table 1), would be based on dbh at the current measurement. Thus, as a tree moves across the dividing dbh from one subplot to another, its expansion factor would change accordingly. However, for option 2 where growth is calculated based on only those trees present at measurement 1, as Y2-Y1, then we should (a) exclude trees coded as "ongrowth" at measurement 2, and (b) use an expansion factor based on dbh at measurement 1.

2.5 Partnerships and Collaborator Responsibilities

The success of large-scale, long-term experiments that span many research topics is difficult for any single organization to achieve. The STEMS experiment has several partners and collaborators who provide critical expertise and leverage.

Various B.C. Ministry of Forests staff are involved:

- The experiment requires that timber harvest preparation and administration be done operationally. Campbell River Forest District and Research Branch staff jointly located experimental areas and treatment units within selected experimental areas for STEMS 1.
- Campbell River Forest District staff were responsible for timber sale preparation and administration through the Small Business Forest Enterprise Program (now restructured as the B.C. Timber Sales Program). Harvesting was done through timber sale licences administered by district staff as part of their forest management operations. The District was responsible for compliance with all applicable forest practice regulations and any other applicable rules.
- Research Branch established and will maintain the permanent plot system, data management, and analyses. The Research Silviculturist for the Coastal Field Experiments program within Research Branch has primary responsibility for data collection and analyses.
- Forest Practices Branch staff are responsible for the Public Perception Study. The study was part of a larger provincial landscape-level survey of public perception of alternative harvesting practices. This report is expected to be published by 2005.
- Vancouver Forest Region Research Section staff helped coordinate the ecosystem mapping and determined the standards for sampling of snags

and coarse woody debris. They will assist in the prescription for recruitment of coarse woody debris over time.

The Forest Engineering and Research Institute of Canada (FERIC) is responsible for the costs and productivity study. They provided the Servis recorders and time sheets for the harvest productivity study. They summarized the time sheets and analyzed the data for final costs of each treatment. They also summarized the soil compaction and residual tree damage data. The study was published as a FERIC report (Evans et al. 2003) and is not included in this report.

Steve Mitchell of the University of British Columbia is responsible for integrating the windthrow data into models and for analysis of the windthrow data.

The USDA Forest Service Pacific Northwest Research Station provides guidance and advice in ensuring compatibility between treatments at STEMS and the Capitol Forest Study, and shares data between the studies under a Memorandum of Understanding.

Additional researchers from government, universities, and other organizations will be encouraged to study various aspects of this project.

3.1 Snowden Demonstration Forest

The first replication of the STEMS experiment (STEMS 1) has been established in the Snowden Demonstration Forest located in the southern portion of the Sayward Landscape Unit within the Coastal Western Hemlock (CWH) xm biogeoclimatic subzone (Green and Klinka 1994). The area was established as a Demonstration Forest in 1987 to raise public awareness about integrated resource management. In this "active" forest, various silvicultural systems were to be integrated with environmental concerns, recreation, education, research, and wildlife management. The area was originally railway-logged between 1929 and 1953 by Bloedel, Stewart and Welch (later known as MacMillan Bloedel). Timber was moved via an intricate system of spurs and mainlines. When the conversion was made to trucks, the rails were removed but, even today, the railway beds (grades) and trestles remain. Three interpretive trails were built to provide examples of old-growth forests, forest ecology, and silviculture treatments. Two self-guided tours highlight elk habitat management and historical points of interest relating to the old railway logging. Numerous recreation trails are available for hiking, mountain biking, running, and mushroom picking.

The STEMS experiment is located at the eastern end of the Snowden Demonstration Forest (see Figure 1). The total area under prescription (including treatment units, reserves, wildlife tree patches, and deferred areas) is 186 ha. The forest in this area is predominantly Douglas-fir, with a minor component of western hemlock and western redcedar. According to plantation maps, the area had been established by planting in 1946 following clearcut logging and burning.

FIGURE 1. *Location of the STEMS experimental site in the Snowden Demonstration Forest.*

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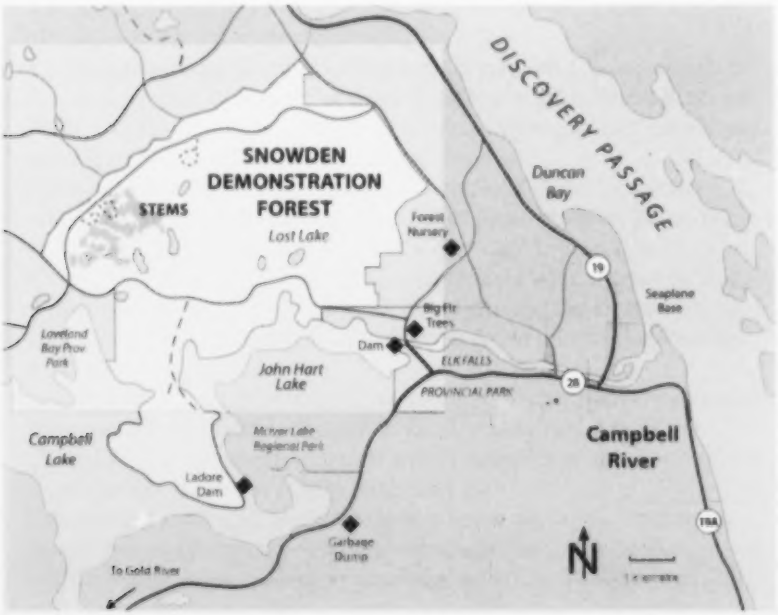

FIGURE 1 *Location of the STEMS experimental site in the Snowden Demonstration Forest.*

3.2 Ecosystem Mapping

Ecosystems were mapped on a 250 ha area at a scale of 1:5000 using a contour base map. Minimum polygon size was 0.1 ha for pure site series units. Composite site series units were acceptable only if they were mosaics of non-mappable site series. Plots were established at subjective locations based on modal stand and ground conditions. Plot size was 20 × 20 m, and five plots were sampled per site series for a total of 25 plots. Each plot was described or measured for site descriptions, vegetation on Dh layer, soils, and mensuration (all tree diameters if > 5 cm dbh, and two dominant tree heights representing the leading species). Standards were based on the work of Meidinger (1998).

Ecosystem mapping of the 250 ha area identified six site series (Figure A1.1), the most common being zonal 01 Douglas-fir–salal (slightly dry to fresh soil moisture regime [SMR] and very poor to medium soil nutrient regime [SNR]) and 05 western redcedar–swordfern (slightly dry to fresh SMR and rich to very rich SNR). Soils were predominantly Ferro-Humic Podzols with moder humus form, sandy-loam structure, coarse fragment content averaging about 40%, and depth averaging 50–80 cm. Other less common site series identified were 02 Douglas-fir–shore pine–Cladina (dry to very dry SMR and very poor to medium SNR) occurring at the tops of rocky knolls; 04 Douglas-fir–swordfern (moderately dry SMR and rich to very rich SNR) found in one small area in the northern portion of the survey area; and 07 western redcedar–foamflower (moist to very moist SMR and rich to very rich SNR) found in riparian areas.

The ecosystem map was used to identify homogeneous treatment units, as described in Section 3.4.

3.3 Resource Assessments

All resource assessments are found in the Silviculture Prescription (Eriksen 2001). Assessments were done on resources referred to under Section 37 of the Operational Planning Regulation. Those particularly relevant to this establishment report are summarized here (see Appendix 1 for corresponding maps).

3.3.1 Wildlife During the assessment and engineering phases, Campbell River Forest District staff and contractors confirmed the presence of the following mammals: black bear, elk, blacktail deer, beaver, and marten. Evidence of the use of the area by the following species was also observed, but not confirmed: cougar, pileated woodpecker, and barred owl. Beaver damage to coniferous and deciduous trees adjacent to wetlands was noted, but damage levels are not expected to change significantly. Elk and blacktail deer are known to use this area, so browsing of regeneration and tree damage by rubbing is expected.

3.3.2 Forest health A root disease survey was conducted in the summer of 2000. *Phellinus weirii*, *Armillaria* spp., and *Fomes annosus* were detected within the area. Overall infection level was estimated at 6.1% within a 250 ha survey area, with *Phellinus weirii* being the primary damaging agent. An objective of the treatment unit designation was to include a more or less equal proportion of root disease within each treatment. Due to distribution and other factors, this was not always possible. No hemlock dwarf mistletoe was observed in the treatment area. (See Figure A1.1).

3.3.3 Windthrow Windthrow is a concern within Block 3, where maintaining about 40 sph is an objective. Manual crown pruning was planned for

about 15–20 sph by removing 30–50% of the tree's crown in a spiralling pattern, evenly distributed around the stem (Stathers et al. 1994).

3.3.4 Visual impact assessment This area is not within a known scenic area and has not been inventoried as visually sensitive. For the first pass, none of the development will be visible from either Snowden or Frog Lake roads. Treatment units 2, 4, and 5 may be visible from the "Lookout Loop" recreation trail, but this has not been confirmed.

3.3.5 Riparian assessment All streams and wetlands within and adjacent to the project area were assessed on two separate occasions by qualified contractors in 2000 (Figure A1.2). Stream classification and riparian prescriptions are based on these assessments. No fish-bearing waters were identified within the project area. Fish were observed in some waterbodies adjacent to and downstream from the classified streams.

3.3.6 Recreation This area has biological and cultural recreational features typical of the Sayward Forest. Cultural features associated with the railway-logging history of the area are present as railway grades, trestles, pilings, sections of rail, spikes, tools, etc. Recreational activities currently pursued in this area include hiking, mountain biking, and hunting. The commercial harvest of chanterelle mushrooms appears to be the highest current use. Several trails within and adjacent to the project area have been previously established via a map notation and public notification (B.C. Gazette). They include general recreation trails, as well as those constructed for education and interpretative use in cooperation with School District 72 (Figure A1.3).

3.4 Description of Treatment Units and Reserves

Treatment units were assigned by using the ecosystem map. The entire area was divided into seven roughly equal treatment units of about 20 ha each, so that each treatment unit consisted of site series 01 and some 05. The treatment units were subsequently numbered 1–7. The seven treatments were randomly assigned to each treatment unit. Once treatments were assigned, the boundaries of the treatment units were then adjusted to approximate the minimum acceptable area per treatment, and modified based on harvest terrain, road location, and site series. Boundaries were then surveyed, and falling corners blazed, numbered, and mapped. These were used as reference points for subsequent plot layout.

Riparian reserves, wildlife tree patches, and deferred areas were mapped out based on resource assessments and the need for protection and enhancement of fish and wildlife habitat, botanical forest products, stand-level biological diversity, and forest health.

Wildlife tree patches (WTPs) are reserves of aggregated trees designated for retention for not less than one rotation. Designated WTPs encompass the range of site series in the area, as well as virtually all the riparian management areas associated with major streams and wetlands. About 24% of the project area (44 ha) has been designated as WTPs.

Temporarily deferred areas (TDAs) are areas to be retained until desired forest conditions develop in the regenerating stand. About 1.5% of the project area (3.2 ha) has been designated as TDAs, and all of these are in Block 1 (aggregate retention treatment).

Individual trees were also left as reserves and include high-value wildlife trees (bear dens, raptor nests, etc.) and old-growth veterans. Also, individual

second-growth western redcedar have been reserved in several areas, primarily for their future wildlife habitat and/or high timber value.

The overall retention of existing forest structure over the areas is estimated at 52 ha or approximately 27% of the gross area (see Figure A1.4). Detailed information about the retention structures and their objectives is described in the Silviculture Prescription (Eriksen 2001) and in Section 5.0. See Tables 2 and 3 for area summaries and site description information.

TABLE 2 *Area summary by treatment unit (operational block)*[a]

Treatment unit		Block boundary (ha)	External reserve (ha)	Total deferred area (ha)	Gross block size (ha)	Permanent access (ha)	Internal reserves (ha)	NAR[b]	TAUP[c,d]
Block 1	a	6.4	0.0	2.0	**8.4**	0.4	0.2	7.8	8.4
	b	11.5	0.0	1.2	**12.7**	0.1	3.2	9.4	12.7
	c	4.4	0.0	0.0	**4.4**	0.7	0.2	3.5	4.4
Subtotal		*22.3*	*0.0*	*3.2*	**25.5**	*1.2*	*2.6*	*20.7*	*25.5*
Block 2		18.6	0.0	0.0	**18.6**	1.2	0.0	0.0	18.6
Block 3		18.2	0.0	0.0	**18.2**	1.3	0.0	16.9	18.2
Block 4		10.9	0.0	0.0	**10.9**	0.7	0.3	9.9	10.9
Block 5		35.7	0.0	0.0	**35.7**	1.2	0.0	3.9	35.7
Block 6		12.0	0.0	0.0	**12.0**	0.0	0.0	0.0	12.0
Block 7		21.6	0.0	0.0	**21.6**	1.0	1.9	2.8	21.6
WTP 1			**5.8**						5.8
WTP 2			**12.3**						12.3
WTP 3			**6.8**						6.8
WTP 4			**7.0**						7.0
WTP 5			**7.4**						7.4
WTP 6			**4.6**						4.6
Total		**139.3**	**43.9**	**3.2**	**142.5**	**6.6**	**4.8**	**54.2**	**186.4**

a Note that the term "block" throughout this manuscript refers to an operational treatment unit, and not the statistical term for site replication as discussed in Section 2.4.

b NAR = net area to be reforested.

c TAUP = total area under prescription.

d TAUP does not include additional adjacent area included in the administrative clearance. Total area under clearance is approximately 297 ha.

TABLE 3 *Site description of STEMS treatment unit (operational block)*

Block		Site series	Total age (2003)	Site height (m)	Site index (m @ 50 yr)	Treatment unit size (ha)	Opening size (ha)	Area harvested (%)
6	Extended rotation (control)	01 (05)	60	31	31	12	0	0
7	Group selection	01/05	60	33	32	21.6	11 groups 0.04–0.5	12
5	Modified patch cuts	01 (03,06)	60	32	31	35.7	0.7, 1.4, 1.8	12
2	Extended rotation with CT*	01 (05,06)	55	33	34	18.6	18.6	100
1	Aggregate retention	01 (05,06)	55	34	35	25.5	4.4, 6.4, 11.5	87
3	Uniform dispersed retention	01/05	55	34	35	18.2	18.2	100
4	Clearcut with reserves	01 (05)	60	34	33	10.9	10.9	100

* Commercial thinning

The harvesting treatments represent a wide range of possible silvicultural systems. As systems, the initial cut is only the first step, and each initial treatment implies a series of subsequent operations extending over the life of the stand. Although the details and timing of these cannot be specified in advance and will depend in part on conditions in the individual stand, the general nature of these operations can be foreseen and is outlined for each treatment in the Silviculture P rescription (Eriksen 2001) and in the following section.

The treatments are listed by treatment unit (operational block) number as follows:

1 = aggregate retention
2 = extended rotation with commercial thinning
3 = uniform dispersed retention
4 = clearcut with reserves
5 = modified patch cuts (0.5–3 ha)
6 = extended rotation (non-treatment control)
7 = group selection (<0.5 ha)

The extended rotations with and without commercial thinning are not silvicultural systems, but a management option to defer the final harvest and reduce the amount of area in the regeneration stage at any given time. A visual overview of the STEMS installation is shown in Appendices 1 and 2.

4.1 Silvicultural Systems

Block 1: Aggregate Retention
Management objective: (see Table 4)

- To retain a component of the existing stand that over the long term will form a bimodal stand structure. Primary objective of the retention is for enhanced visual quality and biodiversity.

Target residual stand structure: Dominant and co-dominant Douglas-fir with a minor component of western redcedar are marked as reserved from cutting in aggregate groups ranging in size from 0.01 to 0.15 ha.

In this operational block, larger retention areas will be left as biological anchors on rocky outcrops (2.14 ha) and in Riparian Management Areas (up to 5.5 ha). See Figure A1.5 for a map of the reserve areas.

Future management: Retain leave trees for a full rotation (80 years). Trees that blow down or die will be assessed individually, but are generally not intended to be salvaged.

Block 2: Extended Rotation with Commercial Thinning
Management objectives (see Table 5):

- To extend the culmination of physical rotation of this stand to approximately 140 years. Tree and Stand Simulator (TASS) modelling estimates physical culmination of this stand at about age 80 if left unthinned.
- To maintain sufficient growing stock to allow for at least one more thinning entry.

TABLE 4 *Description of aggregate retention structures. Note that individual western redcedar trees throughout cutblocks 1a and 1b have been marked to reserve from cutting.*

Reserve #	Area (ha)	Classification	Objective/ function	Feature / stand structure
R1	0.05	Retention	Influence, visual screen, potential future wildlife/ nest trees	Two large Douglas-fir with crooks in lower 1/3, some alder, and a single Sitka spruce
R2	0.02	Retention	Influence, visual screen, rare species (yew)	Douglas-fir, hemlock, and a single Pacific yew
R3	0.02	Retention	Influence	F8C2 with some Cw logs (CWD) are not to be disturbed
R4	2.14	Retention	Influence	Rock outcrop and 03 site series with predominantly Fdc scrub
R5	0.01	Retention	Influence	F7C3 and a single 70 cm dbh western redcedar
R6	0.03	Retention	Influence	F8C2. Site is below a rock outcrop.
R7	0.02	Retention	Influence, root disease amelioration	F5C5. Site is on the edge of a root disease treatment stratum. Douglas-fir is to be selectively harvested from this area.
R8	0.02	Retention	Influence	F10 and one Fdc 60 cm forked top
R9	0.06	Retention	Influence	F9(CH)1, one Fdc 60 cm, and two fork-topped Fdc
R10	0.04	Retention	Influence, visual screen	F6H2C2, one understory Pw. The site includes part of a root disease pocket.
R11	0.02	Retention	Influence, visual screen	F7C2 + Cw understory. Fdc/Cw 55 cm dbh.
R12	0.15	Retention	Influence, visual screen	Primarily 60–65 cm Fdc, with six to 10 sapling-size redcedar. CWD (Cw/Hw) along lower boundary.
R13	5.5	WTP[a] incorporating: RMA[b] – Stream 11 RMA – Stream 3 RMA – wetland 11	Influence, riparian representation, visual screening of EW2 wetland	F8C1H1. Stand has a good component of western redcedar and large Douglas-fir.
R14	1.0	RMA of stream 3A	Influence, zonal site series representation	F8H1C1
R15	1.5	TDA[c]	Untreated control, windfirm buffer for Block 2, zonal representation	F9CH1 at approximately 900 sph.
R16	0.5	TDA	Windfirm recreation trail buffer	F10
R17	1.2	TDA	Influence, wildlife screen	F8H1C1. Site is scrub timber, dominant sites series is 03. Two Fdc vets near Falling Corner 41.
Individual tree reserves	1	Retention	Root disease amelioration	Areas are infected with *Phellinus weirii* but are also well stocked with Cw (resistant). See site preparation root disease strategy.
Individual tree reserves	2	Retention	Extended rotation/ habitat recruitment	Sapling-size redcedar expected to increase significantly in value over time as grade improves. Also potential future habitat.

a Wildlife Tree Patch
b Riparian Management Area
c Temporarily Deferred Area

TABLE 5 *Stand structure objectives for the extended rotation with commercial thinning treatment unit. Density estimates are based on an operational cruise.*

	Pre-thinning	Post-thinning
Species composition	F8C1H1	F6C4
Density (sph)	1050	350 overstory Fd + 150 understory Cw
Basal area (m^2)	68	36
Average stand diameter (cm)	27.0	30.6
Average height (m)	28.7	30.1
Stand density index	1454	712
Relative density	14	7

- To allow sapling- and intermediate-size western redcedar to mature into high-value pole and piling material.

Thinning type/intensity: This thinning will be across the diameter distribution, with a preference for retention of stems in the larger diameter classes. Intensity is defined as light to moderate.

Future management:

- A second thinning when density and merchantability recover sufficiently.
- Regeneration cutting at a scale and time frame compatible with social and wildlife management objectives (such as wildlife cover constraints).

Approximately 350 crop trees have been marked with blue paint and are reserved from cutting. In addition to these marked trees, the following are reserved from cutting:

1. all western white pine, Pacific yew, and deciduous species.
2. all western redcedar that are 17.5 cm dbh or less.

Block 3: Uniform Dispersed Retention

Management objective:

- To retain a component of the existing stand that over time will result in a bimodal stand structure. The primary objective of this retention is enhanced visual quality and biodiversity, not seed tree regeneration.

Target residual stand structure is 45 stems per hectare (sph). Trees marked to reserve from cutting are predominantly dominant and co-dominant Douglas-fir with a minor component of western redcedar. The licensee is responsible for maintaining 45 sph in an undamaged condition. If and where harvesting is expected to create a void, the licensee must reserve additional trees to meet the retention objective. Some windthrow is expected, so 30–50% of the tree's crown will be pruned in a spiralling pattern on 15–20 sph, evenly distributed around the stem.

Future management: Leave trees are to be retained for one rotation (80 years). Trees that blow down or die will be assessed individually, but are generally not intended to be salvaged.

Block 4: Clearcut with Reserves
Management objective:

- An even-aged stand structure. All merchantable and unmerchantable trees on the area are to be cut, except for a small reserve. Physical rotation is estimated to be in approximately 80 years.

This system is well understood and is included primarily to provide a direct quantitative comparison of costs and outputs with the other systems in the experiment.

Target residual stand structure: A single 0.3-ha reserve at the intersection of Black Dog Main (Old Rail Trail) and Branch 69 will be composed of representative existing stand structure.

Future management: A target of 900–1000 sph at free growing will afford an opportunity for a late commercial thinning entry if desired.

Block 5: Modified Patch Cuts
Management objective:

- The system will achieve a multi-aged mosaic of even-aged patches of predominantly Douglas-fir, while lacking large and visually obtrusive harvest areas. Area regulation over the 80 years will be achieved, based on a net area of 30 ha and a return cycle of 10 years, with a required cut in any given cycle of about 3.75 ha.

"Modified patch cut" incorporates two variations to the classic/legal definitions of this silvicultural system:

1. The patch cuts will not be managed as discrete openings. The intent is area regulation over the entire operational block. Over one rotation, there will be a series of entries with pre-determined opening sizes. Over time, the area will develop as a multi-aged structure, with an equal area represented in eight age classes. This system, therefore, is a hybrid of the selection and patch cut systems.
2. Patch cut size will be larger than the legal definition of 1 ha or less. This was necessary to test a complete range of opening sizes.

Patch cut sizes: For consistency, cutting entries must adhere to one of the following opening size regimes, with the goal of equal representation of each patch size over the 80-year period:

1. 0.5, 1.1, 2.0 = 3.6 ha
2. 0.8, 1.4, 1.7 = 3.9 ha

For the first entry, regime 2 was selected. Note that to achieve the total treatment unit net target area of 30 contiguous hectares, it was necessary to include a larger portion of site series 03 than in other treatment units, as well as areas adjacent to established recreation trails that must be treated carefully. For this reason, areas selected for the current pass were based on the following cutting priority and objectives:

1. root disease amelioration
2. current timber merchantability
3. wildlife forest cover constraints
4. minimization of impacts to the Old Rail Trail and Lookout Loop Trail until recreation objectives have been established for these features.

Target residual stand structure: Individual trees of western redcedar and western white pine will be retained in patch cut 3 to promote species diversity. The other patch cuts do not contain these species.

Block 6: Extended Rotation (non-treatment control)
Management objective:

- An even-aged stand structure with all existing trees to be held on an extended rotation with no intermediate treatments.

These stands will be held on an extended rotation to test if untreated stands can achieve the late-seral attributes described in the Vancouver Island and Sayward Land Use Plans, which could be used for adjusting currently unbalanced age-class distributions, reducing visual impacts on the landscape, and enhancing biodiversity.

This treatment allows comparisons with productivity gains obtainable by the extended rotation with commercial thinning treatment regime and the other silvicultural systems. No harvesting or other stand management treatments are planned but some wildlife and recreation enhancement activities may be done.

Block 7: Group Selection
Management objective:

- The system will achieve a multi-aged mosaic of even-aged groups of predominantly Douglas-fir, lacking large and visually obtrusive harvest areas. To achieve area regulation over 80 years and based on a net area of 20 ha and a return cycle of 10 years, the required cut in any given cycle will be about 2.5 ha.

This treatment resembles the patch cut regime, except that removals will be over a range of small groups of trees to a maximum opening of 0.5 ha. Residual basal area over the unit will be comparable to that of the patch cut regime of the same replications. In the classic definition of this silvicultural system, "group" is defined as those trees within an opening equal to or less than two tree lengths in diameter. In this experiment, due to opening size targets, the system is defined as an opening less than two tree heights on at least one side.

Group sizes: For consistency, cutting entries must adhere to one of the following opening size regimes, with the goal of equal representation of each group selection size over the 80 years (Table 6).

For the first pass, the group designations are listed in Table 7. Given the small variance of the actual size from the target size of 0.05 ha or less, no post-traverse adjustments were deemed necessary.

TABLE 6 *Opening size regimes within group selection treatment*

Group size (ha)	Required number	Area (ha)
0.05	2	0.1
0.1	2	0.2
0.2	2	0.4
0.3	2	0.6
0.4	2	0.8
0.5	1	0.5
Total area		**2.6**

TABLE 7 *Actual versus targeted group size in STEMS 1*

Group number	Target group size (ha)	Actual group size (ha)	Variance (ha)	Variance (%)
GS 4	0.50	0.52	0.02	4
GS 8	0.40	0.41	0.01	2
GS 10	0.40	0.45	0.05	2
GS 1	0.30	0.29	-0.01	3
GS 7	0.30	0.30	0.00	0
GS 3	0.20	0.19	-0.01	5
GS 6	0.20	0.22	0.02	10
GS 2	0.10	0.14	0.04	40
GS 11	0.10	0.13	0.03	30
GS 5	0.05	0.06	0.01	20
GS 9	0.05	0.06	0.01	20
Total	**2.60**	**2.77**	**0.17**	**6.5**

4.2 Reforestation

Artificial reforestation by planting is the strategy for all treatment units except the extended rotations with and without commercial thinning. The regeneration objective is to establish 1200 sph by the regeneration date, and target approximately 900–1000 sph at free growing. Species selection for planting is coastal Douglas-fir (Fdc). We anticipate natural regeneration of western hemlock, although this species may not be considered preferred in any block. Seedling sowing request SL60580 Key # 2001DCR0007 (Fdc) has been assigned to this project.

Block 7, group selection, requires special consideration due to the small size of openings in which Douglas-fir cannot reliably perform well. Therefore, the long-term species composition objective for this block includes establishing a minimum of 300 western redcedar (Cw) per hectare, if required to meet the minimum stocking requirements. The decision to plant Cw will be made shortly before the free growing assessment period.

Stocking standards for all treatment units except 2 and 6 are listed in Table 8. All necessary actions will be taken to ensure that stocking standards are achieved within an acceptable timeframe.

TABLE 8 *Stocking standards to be applied to all treatment units (operational blocks) except 2 and 6*

Assessment dates

Blocks	Regeneration date (years)	Free growing assessment period (years)	
		Early	Late
All	3	8	11

Free-growing stocking standards

	Preferred species		Acceptable species		Post-spacing density (sph)		
Blocks	Species	Minimum height (m)	Species	Minimum height (m)	Min	Max	Max. conifer density (sph)
1, 3, 4, 6	Fdc	4.0	Pw	3.0	900	1100	5000
	Cw	2.0	Bg	3.5			
7	Cw	2.0	Pw	3.0	900	1100	5000
	Fdc	4.0	Hw	3.5			

	Well-spaced trees (sph)				Planned residual basal area (m^2/ha) or Planned residual density (sph)	
Block	Target preferred and accepted	Minimum preferred and accepted	Minimum preferred	Minimum horizontal distance (m)	(Partial cuts, commercial thins, pole harvesting, sanitation and intermediate cuts)	Height relative to competition (% or cm)
1, 4, 5	900	500	500	1.5		150%
3	900	500	400	1.5	45 sph	150%
7	900	500	400	1.5		150%

Additional comments concerning stocking requirements and survey criteria:

1. *Abies* spp. may be considered as acceptable species up to a maximum of 30% of the target stocking standard. Limit application to the lower slopes of operational blocks 3 and 1a.
2. The minimum horizontal distance may be reduced to as low as 1.0 m within and around slash accumulations/piles.
3. Western redcedar and western white pine are the only preferred species in untreated root disease treatment areas.
4. Up to 25 non-crop tree red alder per hectare are allowable in all operational blocks (except 2) at free growing, providing that the distribution is well dispersed.

4.3 Site Preparation

4.3.1 Root disease treatment Stumps will be removed by excavator in root rot areas identified in the survey. Where applicable, a stump must not be removed within 2 m of any individual tree or aggregate reserves.

4.3.2 Slash treatment Roadside slash is to be machine piled in preparation for burning. Within a block setting, the objective is to prepare 1200 plantable spots per hectare. For operational blocks 1, 3, and 4, slash will be machine piled in dispersed piles no larger than 20 m^2 (5 m diameter). For wildlife enhancement in Block 4, the construction of one or two large 50-m^2 piles is an objective; the acceptable location will be pre-determined in consultation with the area forester. For blocks 5 and 7, slash will be machine piled in small piles (20 m^2), or distributed over permanent access trails.

4.4 Vegetation Management

Anticipated brush hazard ratings, brush species, and treatments are as follows:

Site series 01: brush hazard rating Moderate Encroachment of red alder and bracken fern. Individual tree treatment of red alder will likely be required prior to free growing. Chemical treatment is the preferred method.

Site series 03: brush hazard rating Low Encroachment of bracken fern, salal, and red alder. Manual treatment (folding over with a hockey stick or similar device) is recommended for bracken. Harvesting disturbance should sufficiently set back salal. No treatment anticipated.

Site series 05: brush hazard rating Moderate–High Encroachment of red alder and salmonberry (minor). Treatment of both species will likely be required prior to free growing. Chemical treatment is the preferred method.

4.5 Density Regulation

The requirement for density regulation as a basic reforestation treatment in the newly established stands is not anticipated. However, pre-commercial thinning may be considered for other reasons, such as improved wildlife habitat.

Commercial thinning in the matrix between patch cuts was part of the treatment in the Capitol Forest study. However, commercial thinning will not be done at this time, but will be considered in the second patch cut entry, anticipated to be 2011.

5.1 Plot Establishment

5.1.1 Pre-treatment plot establishment Plot establishment was initiated by producing a series of 1:5000 maps for each of the seven treatment units. These maps showed the overall shape of the treatment units and the falling corners. A transparent grid was overlain on each map to determine the best bearing to establish a systematic "strip line" system that would achieve the desired number of plots distributed across the entire treatment unit. For five of the seven treatment units (operational blocks), the distance between parallel strip lines was 65 m. For Block 4, 60-m intervals were required to achieve the required number of plots, and, for Block 6, strip lines were established at 70-m intervals. Distances between strips within a block are constant. This system was chosen to achieve the number of plots required, given the constraints of land area and required setbacks from roads and forest edges. The setback, or minimum distance from roads or boundaries to plot centres, was set at 38 m (average tree height) from the north and 48 m from east, south, and west.

Strip lines were surveyed using a Brunton Pocket Transit mounted on a tripod and an Impulse 200 Laser to determine horizontal distance. Survey strip lines started from a boundary or road and, whenever possible, a falling corner was used as a starting point for the traverse. If no falling corner was suitable to achieve the required number of plots, then distance and bearing to a falling corner were noted.

Distances between plots on a strip line are 65 m. Potential plot centres were marked with flagging tape, and distance checks were conducted to ensure that plots met the required setbacks. Once all of the possible plots on the first strip line within a block were established, the transit was turned exactly 90° from a known plot centre and the appropriate horizontal distance to the adjacent strip was surveyed. This second strip was then established using the same distance, bearing, and setback protocols as used in the first strip. This method continued until all of the grid points and possible plots were noted on the ground and on the map. Suitable plots were marked, and plots not meeting setback requirements (usually one or two plots per block) were noted with an "X" on the map. A site visit by Research Branch staff determined which plots were acceptable. If the required number of plots was not achievable then setback distances were reduced to 43 m from east, south, and west. In the case of six plots throughout the installation, distances between plots on a strip line were reduced from 65 m to 60 m to meet the requirement for minimum number of plots. See plot maps for each block in Appendix 3.

Permanent plot centres in all 142 plots within the seven blocks were permanently marked with a 1-m piece of ⅜-inch rebar driven 90 cm into the ground and then a 1-m piece of PVC driven over the rebar. The 10 cm of PVC and rebar that remained visible above ground was spray painted with "hi viz" fluorescent paint; white flagging was marked, indicating the block and plot number (e.g., 501 = Block 5, plot 1) and tied securely around the PVC. A 1-m white ribbon also denoting block and plot was tied at about 2 m above and as close to the centre pin as possible. Blue and pink striped ribbon was tied to adjacent shrubs at cardinal directions near plot centres. Also, the strip lines were flagged with white to facilitate subsequent plot relocation. It was expected that much of this flagging would be destroyed during logging. To

ensure relocation of plot centres, three reference trees per plot were marked. Reference trees were labelled with a metal tag facing the plot centre; distance and bearing to the plot centre were marked on the 15 × 8 cm label, which was nailed to each tree below the 30 cm height. The area surrounding each label was painted with orange spray paint, and two smaller orange dots were painted on the opposite side of the tree to further aid in post-harvest relocation.

5.1.2 Post-treatment plot re-establishment In harvested treatment units, plots were located by using a compass and measuring tape to find the rebar that marked the plot centres. If the rebar was no longer there, then we looked for the stumps of the bearing trees to give the exact distance and bearing from three points. If the stumps had been removed or displaced, then the plot centre was re-established by surveying. Stumped areas needed the most plot re-establishment, especially in Block 4.

5.2 Pre-treatment Measurements and Assessments

Pre-treatment measurements were made between January and March 2001. All data were recorded electronically on Juniper Systems Allegro Field PC using EASYDC software licensed to the Research Branch of the B.C. Ministry of Forests. An application developed using EASYDC became the property of the Research Branch under the terms of the consulting services contract.

See Appendix 4 for detailed descriptions of the following pre-treatment measurements:

- tree measurements
- stump measurements
- vegetation measurements
- plot photographs
- coarse woody debris measurements

5.3 Post-treatment Measurements and Assessments

Post-treatment measurements were made between October 2002 and March 2003. A series of post-treatment measurements was recorded on the following parameters:

- residual tree measurements
- residual tree harvest damage
- tree regeneration
- vegetation assessments
- coarse woody debris
- soil disturbance
- windthrow surveys

For detailed information, see Appendices 5–8.

The original intent of the experiment was to harvest the area under contract as a log sale and to sell the logs to the highest bidder. This would have allowed us the greatest control over how and when the harvesting is done. However, because this approach would have cost the B.C. Ministry of Forests over $1 million in advance, the proposal was rejected. The alternative was to proceed with a timber sale.

Three timber sale licences were awarded through the Small Business Forest Enterprise Program (SBFEP, recently made a Crown Corporation called B.C. Timber Sales) as follows:

- A66727 for operational blocks 1 and 4
- A67228 for operational block 3
- A66730 for operational blocks 2, 5, and 7

6.1 Timber Sale Licence A66727

6.1.1 Block 1: Aggregate Retention Block 1 had a net area of 19.7 ha. The total gross merchantable volume was 9412 m^3, based on cruise data. Harvesting began October 1, 2001, by hand falling and loader forwarding. Harvesting was not completed within the term of the original licence, despite commitments to complete operations by November 30, 2001. As a result, the licence was extended to February 28, 2002. In mid-January, decked wood was at roadside, and areas still required yarding. On February 12, the licensee was advised that site preparation was incomplete because decked wood covered stumps along roadsides. A waste assessment survey indicated that utilization was about 20 m^3/ha and more on the roadside. The licensee argued that he could not find a log buyer for this small wood. He was advised that the wood must be removed or it would be waste scaled. Eventually, the SBFEP paid to have the timber piled onto the roads and waste billing was processed.

Planting of Block 1 began March 5–8 before primary harvesting and site preparation (stumping) had passed inspection. The Post Harvest Inspection (PHI) revealed that an unacceptably high number of stumps had been missed, which was in contravention of the Silviculture Prescription (SP) objectives. A survey confirmed this observation. Due to the unacceptable risk of *Phellinus* re-infection in Block 1a, the seedlings were pulled and buried, and the area was reworked by contract with a Hitachi Ex 200. During the rework, even more stumps were discovered under slash piles, further confirming the poor quality as well as the necessity to rework. Site preparation was completed by early April 2002, and the areas replanted the same week with the proper seedlot, but with two different stock types (1+0 PSB 615 and 415s).

6.1.2 Block 4: Clearcut with Reserves The gross area for Block 4 is 10.9 ha with a 0.3-ha internal reserve. Estimated stand density was 694 sph and total gross merchantable was 5349 m^3. Hand falling began October 1, 2001, and was completed by October 15. Yarding was done with loader forwarders. On October 11, the log broker shut down the operation for "administrative reasons." The dispute was resolved October 24, with the result that a scaler remained on site to ensure that outgoing loads were to log buyers' specifications. This produced "mountains of wood" decked on the roadside that took many weeks to haul out. Stumping began after October 30, which

required an SP amendment. By November 6, all yarding and stumping had been completed within the block, but stumping had not been done on the roadsides because of the large amount of wood remaining.

Strong winds on November 14 caused some windthrow along the west boundary of Block 4. Wind events on November 20 and December 15 caused some blowdown and leaning in the reserve. The cumulative effect was blowdown of about 35% of the reserve (0.1 ha).

Planting in Block 4 began before primary harvesting and site preparation (stumping) had passed inspection. A Post Harvest Inspection (PHI) revealed that many stumps had been missed, in contravention of the SP objectives. A secondary observation was that the distribution of stumps and slash was inconsistent with other treatment areas, which potentially compromised coarse woody debris research objectives. A follow-up stumping survey confirmed this observation. Due to the unacceptable risk of *Phellinus* re-infection, and the coarse woody debris research objectives, the areas were reworked. The planted seedlings were pulled and buried, and the SBFEP hired a contractor to rework the area. During the rework, stumps were discovered under slash piles, further confirming the poor quality. Site preparation was completed by April 1, 2002, and the restumped areas were immediately replanted the same week with the same seedlot (2001DCR0007/60580) and stock type (PSB 415D 1+0).

6.2 Timber Sale Licence A67228 for Block 3: Uniform Dispersed Retention

Block 3 is 18.2 ha in area and, prior to harvest and based on cruising data, contained 832 sph and a total gross merchantable volume of 8088 m^3. The licensee began work July 16, 2001, using chainsaw falling and loader forwarders. All trees had been previously marked to leave. Scars on retention trees were noted, and, on August 16, the licensee was advised of excessive scarring of residual trees and the need to slow down and work more carefully. Compliance and Enforcement fined them $175 for scarring to reserve trees. Also, it appeared that site degradation could be occurring on short pitches of slopes >30%, although this was found to be in compliance. All harvesting activities were finished by October 1, 2001. The target number of leave trees per hectare was set at 45; the average found was 44.

Trees were marked for spiral pruning (seven trees/ha, 30–50% of live crown to be removed in a spiral fashion over entire live crown) as logging progressed. Trees were pruned by late October. On November 14, a wind event caused windthrow of 21 trees; only one had been spiral pruned. Two more wind events on November 18 and December 14 caused additional windthrow. After the winter wind events, the number of leaves trees per hectare dropped to 33.

The PHI determined that piling slash was largely unnecessary. The licensee was advised that slash loads were acceptable and no further piling was required. The licensee completed stumping. Block 3 was planted in mid-March 2002 at 1200 sph with seedlot 2001DCR0007/60580 and stock type PSB 415D 1+0.

6.3 Timber Sale Licence A66730 for Blocks 2, 5, and 7

6.3.1 Block 2: Extended Rotation with Commercial Thinning The net area for Block 2 is 18.6 ha. The block contained an average of 532 sph and had a total gross merchantable volume of 3532 m^3, based on cruising data. Trees were marked to leave prior to harvest by contractor and remarked to ensure the desired residual diameter distribution. Thinning began on July 26 using

mini-towers. Two Skylead towers were used simultaneously. Work progressed without problems. "Normal levels" of reserve tree damage along yarding corridors were noted. As planned, the area was not planted. Windthrow occurred near Br 70 in late 2001.

6.3.2 Block 5: Modified Patch Cuts Patch sizes were 0.8, 1.4, and 1.7 ha. The average stand density in Block 5 was 967 sph and the total gross merchantable volume was 1898 m^3 distributed over three patch cuts totalling 3.9 ha. The licensee began harvesting July 16. The trees were hand felled and yarded using loader forwarding and cable yarding. Work progressed uneventfully except that the yarding corridor for patch cut 1 was cut to 6 or 7 m wide rather than the prescribed 4 m.

In patch cut 1, due to a misunderstanding by the licensee, all stumps were uprooted, including old growth, redcedar, and deciduous stumps, although this was not required. As well, slash piling and utilization of small-diameter wood was unsatisfactory. In contrast, in patch cuts 2 and 3, the stumping survey confirmed that an unacceptable number of stumps were missed. The areas were reworked by SBFEP contract as well.

Patch cuts 1, 2, and 3 were planted immediately after the reworking on April 4, 2002 at 1200 sph using seedlot 2001DCR0007/60580 and stock type PSB 415D 1+0.

6.3.3 Block 7: Group Selection Group selection cutblock sizes in hectares were as follows (GS 1–11, respectively): 0.29, 0.14, 0.19, 0.52, 0.06, 0.22, 0.30, 0.41, 0.06, 0.45, and 0.13. The gross harvest area was 2.8 ha; based on cruising data, the pre-treatment density was 819 sph and total gross merchantable volume was 1336 m^3. Because the licensee did not own the specified equipment to log Block 7, they contracted the work. The contractor began harvesting July 5 using his small hoe/farm tractor forwarder, and completed group selections GS 1 through GS 8 by mid-August. Citing personal and financial reasons, the licensee attempted to have his stumpage bills reduced but was denied. His endeavours delayed completion of harvesting activities and resulted in his cancelling the contract. Group selections GS 9 and GS 11 were completed by another contractor, who used a skidder swing system to extract the timber.

Group selections GS 3, GS 4, and GS 8 had root disease pockets requiring stumping. The work was initially performed by the licensee but the PHI and stumping survey revealed 100 and 150 missed stumps per hectare in group selections GS 4 and GS 8, respectively. Group selection GS 3 was the only area of all the areas treated that was done satisfactorily. Group selections GS 4 and GS 8 were reworked by contract under SBFEP supervision.

Planting immediately followed the rework of the site-prepared areas on April 2 and 3, 2002 at 1200 sph using seedlot 2001DCR0007/60580 and stock type PSB 415D 1+0.

Strong winds on November 14, 2001 caused some windthrow along the west boundary of group selections GS 1 and GS 2.

Photographic examples of each treatment are shown in Figures 2–8.

FIGURE 2 *Block 1 – Aggregate Retention.*

FIGURE 3 *Block 2 – Extended Rotation with Commercial Thinning.*

FIGURE 4 *Block 3 – Uniform Dispersed Retention.*

FIGURE 5 *Block 4 – Clearcut with Reserves.*

FIGURE 6 *Block 5 – Modified Patch Cuts.*

FIGURE 7 *Block 6 – Extended Rotation (non-treatment control).*

FIGURE 8 *Block 7 – Group Selection.*

7.1 Pre- and Post-harvest Stand Statistics by Treatment

According to old plantation maps, the area had been established by planting in 1946 following clearcut logging and burning. However, individual tree ages were found to vary considerably. Average age in 2003 was 60 years in blocks 1, 5, and 7 and 55 years in blocks 2, 3, and 4. Further work is needed to more accurately determine average ages for each operational block.

A comparison of pre- and post-harvest stand statistics by treatment is given in Table 9. The treatment unit differences were compared using the average of plots sampled within treatment units. Note that while the post-treatment summaries are based on the 0.10-ha plot, those for pre-treatment (except blocks 4 and 6) are based on the 0.01-ha plot. Therefore, larger trees may be under-represented. Block 4 had the full 0.10-ha plots measured because it was to be completely harvested, and Block 6 had the full 0.10-ha plots measured but only at the time of post-treatment (to save costs).

The densities of blocks 1–3 were significantly greater than of blocks 4–7. In addition to higher density, blocks 1–3 had smaller quadratic mean diameters (QMDS) and a larger proportion of western hemlock and western redcedar than blocks 4–7. Block 2 had significantly higher basal area and relative density than all other blocks. Blocks 1 and 3 had significantly smaller QMDS than blocks 4, 6, and 7.

Pre-treatment volume by species and treatment unit is shown in Table 10. Total volume of Douglas-fir was highest in Block 7 and lowest in Block 2, while volume of western hemlock was the opposite: lowest in Block 7 and highest in Block 2. Total volume of western redcedar was highest in blocks 1 and 2 and was sparse in blocks 4–7. Sitka spruce and western white pine were found in trace amounts in blocks 4 and 5, and red alder was found in trace amounts in blocks 3, 4, 6, and 7. Block 5 had the lowest overall density but had a larger proportion of drier 01 sites series than other blocks.

Post-treatment volume by species is also shown in Table 10. The proportion of standing volume of Douglas-fir increased relative to the pre-treatment condition in the commercial thinning and dispersed retention treatments, remained about the same in the group selection treatment, and decreased in the aggregate retention, patch cut, and clearcut treatments.

TABLE 9 *Pre- and post-harvest stand statistics by treatment unit. Similar letters indicate no significant pre-treatment difference between treatment units (operational blocks), based on plot averages.*

Treatment block	Density (stems/ha)			QMD (cm)		Basal area (m^2/ha)			Total volume (m^3/ha)			Merchantable volume (m^3/ha)			Relative density	
	Pre	Post	% change	Pre	Post	Pre	Post	% change	Pre	Post	% change	Pre	Post	% change	Pre	Post
1	1208 b	247	80	25.0 a	26.5	55 b	10	82	571 a	96	83	521 b	86	83	11 b	4
2	1325 b	636	52	26.3 ab	27.3	69 c	37	46	712 b	388	46	651 c	359	45	14 c	7
3	1210 b	51	96	24.6 a	38.2	55 b	6	89	581 ab	57	90	530 b	54	90	11 b	1
4	747 b	0	100	30.1 bc	00	53 ab	0	100	587 ab	0	100	551 ab	0	100	9 ab	0
5	763 a	575	25	28.0 ab	27.3	44 a	36	18	452 a	372	18	418 a	345	17	8 a	7
6	607 a	607	0	33.1 c	33.1	53 ab	53	0	610 ab	610	0	580 ab	580	0	9 ab	9
7	725 a	578	20	28.5 bc	28.5	48 ab	41	15	499 a	405	19	465 ab	381	18	9 a	8

TABLE 10 *Total volume by treatment block and species (%)*

Treatment block	Tree species															
	Douglas-fir		Western hemlock		Western redcedar		Sitka spruce		Western white pine		Red alder		Total conifer		Total broadleaf	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	77	34	14	10	9	56	0	0	0	0	0	0	100	100	0	0
2	71	78	20	8	9	13	0	0	0	0	0	0	100	100	0	0
3	79	96	16	0	4	4	0	0	0	0	2	0	98	100	2	0
4	85	0	10	0	0	0	1	0	0	0	3	0	97	0	3	0
5	87	82	12	8	1	7	0	2	0	1	0	0	100	100	0	0
6	88	88	10	10	0	0	0	0	0	0	1	1	99	99	1	1
7	92	93	7	6	0	0	0	0	0	0	1	1	99	99	1	1

Western hemlock decreased in all harvested blocks. The proportion of standing volume of western redcedar was maintained or increased in harvested blocks where possible, and increased significantly in the aggregate retention and commercial thinning treatment units.

The prescription for the post-thinning density in Block 2, extended rotation with commercial thinning, was to leave 350 overstory crop trees and 150 understory western redcedar. The post-thinning density was much higher than expected. The species breakdown by diameter class (Figure 9) was about 325 trees in the 25 cm or larger diameter class, and about 100 western redcedar and 225 Douglas-fir and hemlock below the 25 cm diameter class. The higher residual density was due to the many small marked trees that were left because they were not economical for the licensee to remove. These small Douglas-fir and western hemlock are not likely to affect the overstory trees or the smaller western redcedar and will be left.

7.2 Regeneration

Regeneration surveys were done on all regeneration plots that had been planted. The number of regeneration plots that were in cutblock openings and therefore planted varied with treatment unit. In blocks 3 (uniform dispersed retention) and 4 (clearcut with reserves), where the entire block was regenerated, all regeneration plots were planted. In Block 1 (aggregated retention) only 86% of the regeneration plots were planted, the remainder of the plots were in retained aggregates and therefore not regenerated. In blocks 5 (patch cut) and 7 (group selection), 16% and 20% of all regeneration plots were in cutblock openings requiring planting, respectively. The regeneration target was 1200 sph but, as indicated in Table 11, after the first year, density was substantially lower especially in blocks 1 and 7. First-year mortality was highest in blocks 1 (aggregate retention) and 4 (clearcut). All blocks were fill planted in late winter of 2003, and regeneration surveys in July 2003 indicated that all blocks were much closer to the target, although blocks 1 and 7 were still below, and that 13–25% of total seedlings had been replanted.

Elk damage appears to be a serious issue. A resident elk herd is often seen browsing on seedlings over the winter and early spring. The elk not only strip the trees of foliage, but also pull the entire seedling out of the soil. This is the

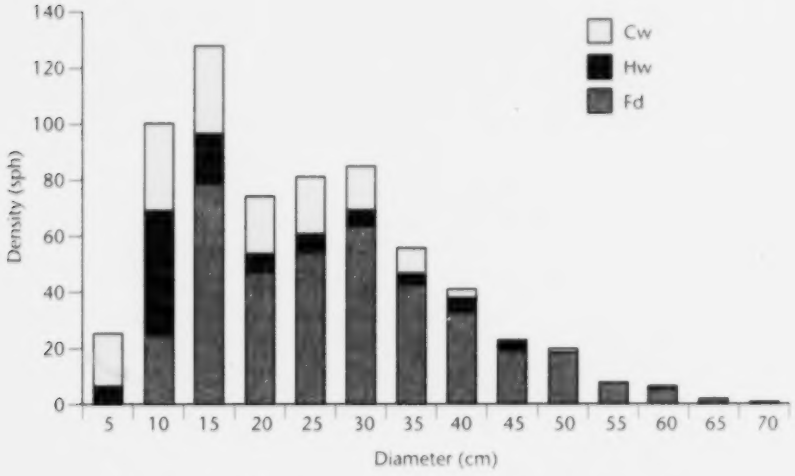

FIGURE 9 *Diameter distribution by species in Block 2, Extended Rotation with Commercial Thinning.*

TABLE 11 *Regeneration survey results in planted plots after 1 and 2 years*

				1-year survey results			2nd-year survey results					
Treatment block	**Total number of regeneration plots**	**Number of regeneration plots planted**	**% of all regeneration plots planted**	**Live planted seedlings (sph)**	**Mortality/ ha**	**% mortality**	**Total live planted seedlings/ ha**	**% replanted**	**Browsed live seedlings/ ha**	**% seedlings browsed**	**Dead seedlings/ ha**	**% mortality**
1	104	89	86	831	58	7	1063	18	214	20	134	11
2	64	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	84	84	100	1129	24	2	1205	17	203	17	76	6
4	60	60	100	1043	87	8	1263	24	393	31	163	11
5	108	17	16	1013	3	0	1150	13	163	14	100	8
6	68	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7	80	16	20	870	20	2	1025	25	407	40	150	13

likely reason that regeneration density remains lower than the target, especially in blocks 1 and 7. Browsing on live seedlings was noted in the second-year survey, with block averages ranging from 14 to 40% of seedlings browsed. Browsing appeared highest on the group selection block and in the clearcut.

Mortality after the second year was lowest on Block 3 (6%) and highest on Block 7 (13%). Mortality includes all dead, missing, and pulled seedlings.

7.3 Vegetation

A summary of the percentage cover on vegetation plots surveyed 2 years after harvest is shown in Table 12. There were no undisturbed plots on blocks 2 (dispersed retention), 3 (commercial thinning), and 4 (clearcut with reserve) and there were no disturbed plots on Block 6 (extended rotation). In general, trees and shrubs in the A and B1 layers were more abundant in undisturbed plots, but trees in the B2 layer and herbs in the C layer were more abundant in the disturbed plots. As expected, woody debris was higher in the disturbed plots, and highest total percent cover occurred on the undisturbed plots.

7.4 Soil Disturbance

Levels of soil disturbance for each treatment (Table 13) were well below allowable maximums for strata that were not stumped. The lowest levels of soil disturbance, from 0 to 0.5% of the area, occurred in areas that had not been stumped in the patch cut, group selection, and extended rotation with commercial thinning treatment blocks. Slightly higher levels, from 0.8 to 3.6% of the area, were found in the treatments that had loader forwarding activity in the clearcut, aggregate retention, and dispersed retention blocks. Levels of disturbance were highest for stumped areas (5.8–12.7% of the area), but these levels were within acceptable limits.

7.5 Harvesting Damage to Residual Trees

Tree damage (Table 14) was highest in the dispersed retention treatment unit, with 17% of total retained trees showing damage, primarily caused by forwarding activities. The extended rotation with commercial thinning treatment had the next highest damage, at 15%. Damage was confined mostly near the base of standing trees and occurred when yarded stems rubbed against the residual trees during yarding. Treatments showing the lowest levels of residual tree damage were the aggregate retention, group selection, and patch cut treatments, with 3, 1, and 0% damage, respectively. In the dispersed retention treatment, 81% of the damage could be attributed to loader forwarding, while in the extended rotation with commercial thinning treatment, 88% was attributed to cable yarding activities. The aggregate retention treatment had 60% of tree damage caused by falling and 30% by excavator forwarding.

7.6 Windfall Losses

Major wind events occurred in November and December 2001 and in December 2002. Windthrow losses were very high in the dispersed retention block. Only 38% of the residual trees were still standing straight after 2 years, and another 15%, although still standing, were leaning. All trees that had spiral pruning (seven trees/ha, 30–50% of live crown removed in a spiral fashion over entire live crown) were still standing straight. A full 47% of residual trees were uprooted in the dispersed retention block. By comparison, in the aggregated retention block, 8% of trees were uprooted, and in the extended rotation block, 4% were uprooted. See Table 15 for percentages of residual trees affected by windthrow.

TABLE 12 *Summary of vegetation (percent cover) for vegetation plots by treatment unit (operational blocks)*

		Vegetation cover (%)													
		Block 1		Block 2		Block 3		Block 4		Block 5		Block 6		Block 7	
Layer	Grouping	Dis[a] (N=89)	Undis[b] (N=15)	Dis (N=64)	Undis (N=0)	Dis (N=84)	Undis (N=0)	Dis (N=60)	Undis (N=0)	Dis (N=27)	Undis (N=81)	Dis (N=0)	Undis (N=68)	Dis (N=20)	Undis (N=60)
A	Trees	1.07	33.13	40.56	N/A	2.27	N\A	0	N/A	10.93	48.91	N/A	43.50	6.60	47.78
		(0.46)	(3.79)	(2.38)		(0.72)		(0)		(3.43)	(1.82)		(1.79)	(2.54)	(1.43)
B1	Trees	0.03	3.87	2.94	N/A	0.01	N\A	0	N/A	0.22	1.32	N/A	2.10	1.30	0.82
		(0.03)	(0.91)	(0.62)		(0.01)		(0)		(0.13)	(0.24)		(0.35)	(1.03)	(0.21)
	Shrubs	0.01	2.20	0.59	N/A	0	N\A	0	N/A	0.19	1.09	N/A	0.62	0	0.64
		(0.01)	(2.20)	(0.25)		(0)		(0)		(0.09)	(0.80)		(0.22)	(0)	(0.37)
B2	Trees	0.44	0.41	0.68	N/A	0.65	N\A	0.59	N/A	0.48	0.06	N/A	0.06	0.60	0.04
		(0.05)	(0.23)	(0.28)		(0.09)		(0.06)		(0.10)	(0.04)		(0.05)	(0.13)	(0.03)
	Shrubs	5.01	26.73	13.22	N/A	7.44	N\A	4.93	N/A	34.11	41.17	N/A	26.35	9.75	26.43
		(0.44)	(4.75)	(1.57)		(0.83)		(0.44)		(5.09)	(2.33)		(2.48)	(2.20)	(2.22)
C	Herbs	4.23	2.40	6.05	N/A	7.83	N\A	10.37	N/A	7.37	3.79	N/A	8.40	7.8	4.90
		(0.41)	(0.49)	(1.44)		(0.69)		(1.43)		(1.44)	(0.56)		(0.86)	(1.92)	(0.56)
D	Bryoids	10.61	66.33	67.58	N/A	24.24	N\A	1.09	N/A	31.67	77.53	N/A	62.07	29.9	84.82
		(2.05)	(6.12)	(3.21)		(2.31)		(0.23)		(5.90)	(3.09)		(3.79)	(6.47)	(2.78)
	Debris	13.35	3.47	6.77	N/A	11.65	N\A	10.03	N/A	9.89	1.79	N/A	1.24	13.5	2.53
		(1.76)	(0.73)	(1.23)		(1.20)		(1.71)		(2.55)	(0.23)		(0.15)	(2.93)	(0.36)
All	All	34.19	99.13	89.89	N/A	48.17	N\A	27.18	N/A	75.89	99.84	N/A	99.9	66.45	99.40
		(2.51)	(0.50)	(1.50)		(2.49)		(1.96)		(5.29)	(0.05)		(0.04)	(6.25)	(0.27)

a Disturbed plots have had harvest activity.
b Undisturbed plots have not had harvest activity.

TABLE 13 *Soil disturbance by stratum*

Stratum	Block	Site series	Stumped	Area (ha)	Max. soil disturbance area (%)	Counted soil disturbance (mean%)	Counted soil disturbance (LCL%)	Counted FF* disturbance (Mean%)	Counted FF disturbance (LCL%)
1	1	01	Yes	7.4	10	7.3	4.9	22.4	18.8
2	1	01	No	10.1	5	2	0.7	4.4	2.5
3	1	05	No	2.8	5	2.6	1.2	3	1.4
4	1	05	Yes	0.4	10	13.1	10.3	29.5	25.8
5	2	01/05 (07,06,03)	No	18.6	2.5	0.5	-0.6	1.9	0.4
6	3	01	Yes	1.3	10	12.7	10.5	20.9	17.3
7	3	01	No	11.3	5	2.7	1.2	0.8	-0.1
8	3	05	No	4.3	5	4.6	3.2	1.5	0.6
9	4	01	Yes	4.4	10	6.6	4.4	22.1	18.4
10	4	01/05	No	5.5	5	0.8	-0.2	6.2	4
11	5	01	Yes	1	10	5.8	3.7	23.5	19.8
12	5	01/05(03)	No	2.8	5	0	0	0.4	-0.1
13	7	01	Yes	1.1	10	6.6	3.3	28.3	24.1
14	7	01/05	No	1.6	5	0.4	-0.3	1.1	0.1

* Forest floor

TABLE 14 *Incidence of tree damage by treatment unit (operational block)*

Block no.	Trees sampled	CFS damage classification: Trees with damage (all depths) (%)	Trees with phloem exposed or gouged (damage ≥ B class) (%)	Avg. scar area (cm^2)	Avg. scars/ tree	Avg. scar height above ground (m)	Distribution of damages by depth class: Class A (surface bruised – phloem not exposed) (%)	Class B (phloem exposed) (%)	Class C (wood gouged <1 cm deep) (%)	Class D (wood gouged ≥1 cm deep) (%)	Class E-g (tree stem damaged at ground) (%)	Class E-m (main root system damaged) (%)	Distribution of damages by cause: Falling (%)	Yarding (%)	Windfall (%)
							Treatment								
1 Aggregate retention	293	3	3	1186	1	1.19	0	40	50	10	0	0	60	30	10
2 Extended rotation with commercial thinning	614	15	12	885	1	0.71	25	73	0	2	0	0	12	88	0
3 Uniform dispersed retention	93	17	16	801	1	1.24	6	88	6	0	0	0	0	81	19
5 Modified patch cuts	969	0	0	3675	1	0.03	100	0	0	0	0	0	100	0	0
7 Group selection	812	1	1	1557	1	1.53	0	29	43	14	0	14	57	14	14

TABLE 15 *Percentage of residual trees still standing, uprooted, or leaning after 2 years*

Block	Tree condition		
	Standing	Uprooted	Leaning
6 Extended rotation (control)	99.5	0.1	0.0
7 Group selection	98	1	1
5 Modified patch cuts	96	1	0
2 Extended rotation with CT*	92	4	3
1 Aggregate retention	82	8	10
3 Uniform dispersed retention	38	46	15
4 Clearcut with reserves	0	0	0

* Commercial thinning

Windthrow around block boundaries was surveyed, and the corresponding maps are shown in Appendix 3. The clearcut (Block 4) and dispersed retention were the hardest hit. Windthrow occurred to some degree at all cutblock edges.

In June and July, 2003, windthrow was salvaged in blocks 1 (aggregate retention) and 4 (reserve and edges around the clearcut) using ground-based systems, and in Block 3 (dispersed retention) using a helicopter. Total volume removed was 914 m^3, with all volume from Block 3 (280 m^3) removed by helicopter.

8 SUMMARY

The Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) project is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of seven silvicultural systems or extended rotation treatments replicated at three sites in the Sayward Forest, near Campbell River, B.C. The treatments include extended rotation (non-treatment control), extended rotation with commercial thinning, uniform dispersed retention, aggregate retention, group selection (<0.5 ha), modified patch cuts (0.5–3 ha), and clearcut with reserves.

These silvicultural systems and treatments create diversity in forest structure that results in a variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure) to enhance biodiversity and wildlife. The resulting range in gap sizes and frequencies emulates natural variation in forest structure.

STEMS is a replication of the project "Silvicultural Options for Harvesting Douglas-fir in Young-Growth Production Forests" in the Capitol Forest near Olympia, Washington. Data sharing between the B.C. Ministry of Forests and the USDA Pacific Northwest Research Station will greatly enhance the statistical power of the overall experiment and the ability to extrapolate over wide geographic regions.

The first replication (STEMS 1) was established in the Snowden Demonstration Forest and harvested through the Small Business Forest Enterprise Program of the Campbell River Forest District in 2001. The second replication will be established near Elk Bay and harvested by Interfor in 2004/05. The third replication is currently scheduled for harvesting in 2007.

The Snowden Demonstration Forest is located in the southern portion of the Sayward Landscape Unit on eastern Vancouver Island. The area was originally established as a demonstration area in 1987 to raise public awareness about integrated resource management with the intent to integrate various silvicultural systems with environmental concerns, recreation, education, research, and wildlife management. The forest is predominantly Douglas-fir, with a minor component of western hemlock and western redcedar. Based on ecosystem mapping and resource assessments, seven treatment units roughly similar in site series and presence of root rot were delineated. Treatments were randomly assigned and boundaries surveyed. The total area under prescription is 186.4 ha, the area within treatment unit boundaries is 139.3 ha (75% of the gross area), and the areas of retention (including internal and external reserves, not including individual tree reserves) is 52 ha (27% of the gross area).

Ongoing studies at STEMS 1 include:

- a forest productivity study, including
  - tree growth and stand development including understory vegetation
  - regeneration and light availability
  - windthrow, mortality, and coarse woody debris recruitment
- a study on harvesting production and impacts of residual tree damage and soil disturbance (in partnership with FERIC)
- a study on visual quality and public response (in partnership with the Forest Practices Branch)

This report covers only the Forest Productivity study of the STEMS project. Results of the harvesting productivity and impacts study were published by Evans et al. (2003).

Initial results are that:

- Levels of soil disturbance for stumped and not stumped areas were within acceptable limits.
- Damage to residual trees appeared highest in commercial thinning and dispersed retention treatment units.
- Regeneration surveys show that elk browsing appears to be a serious issue.
- Windthrow losses were very high in the dispersed retention block.

Continued monitoring of the STEMS experiment will help to determine how best to meet the operational goals and targets set out in the Vancouver Island and Sayward Land Use Plans for multiple-use objectives. The results of this experiment will be used to improve forest management decision-making and policies regarding alternatives to clearcutting.

FIGURE A1.1 *Ecological classification of STEMS treatment units by site series.*

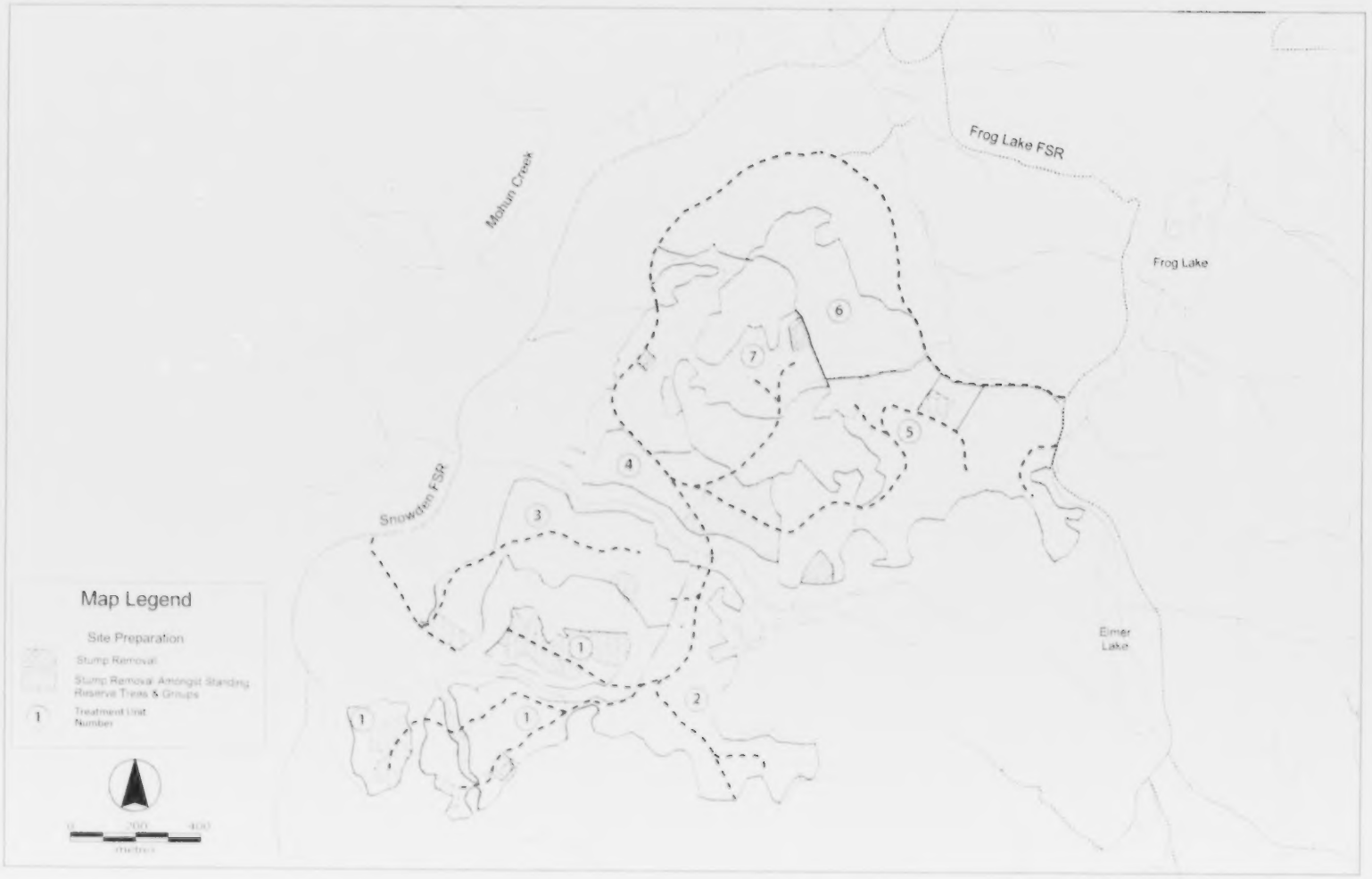

FIGURE A1.2 *Areas requiring stump removal site preparation for root rot*

FIGURE A1.3 *Streams and wetlands within STEMS treatment unit.*

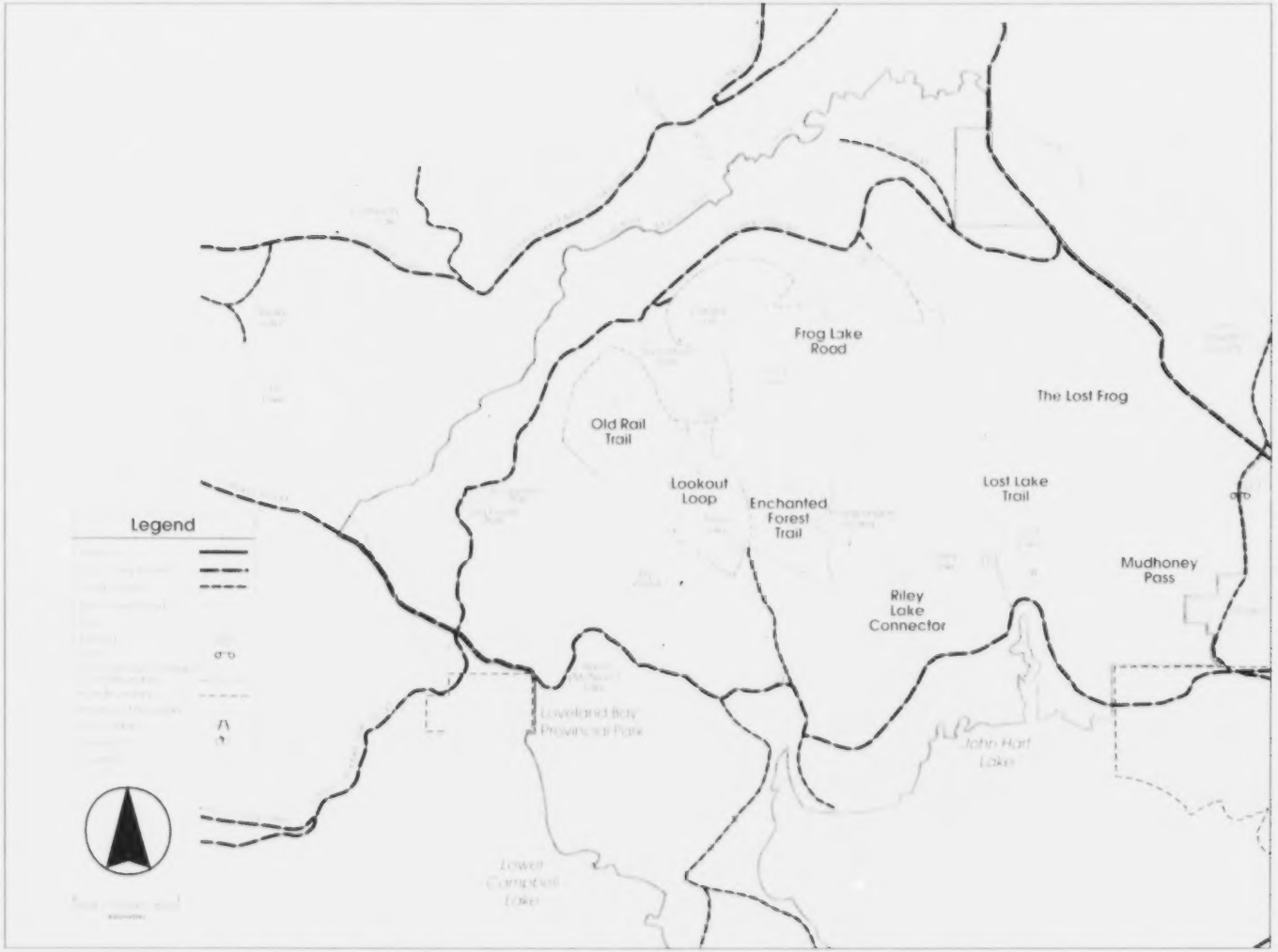

FIGURE A1.4 *Recreational trails within the Snowden Demonstration Forest.*

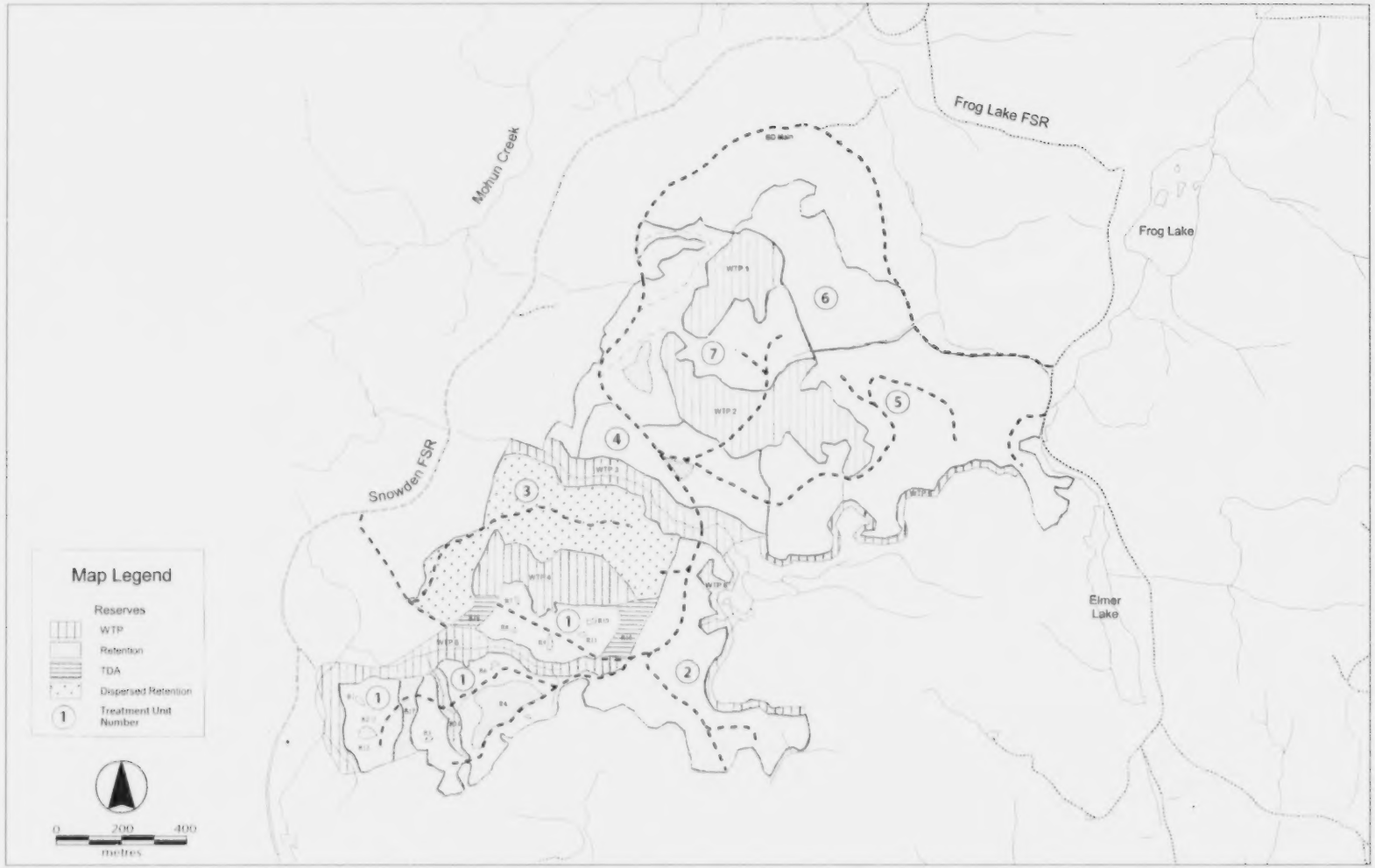

FIGURE A1.5 *Reserve area classification within the STEMS treatment units.*

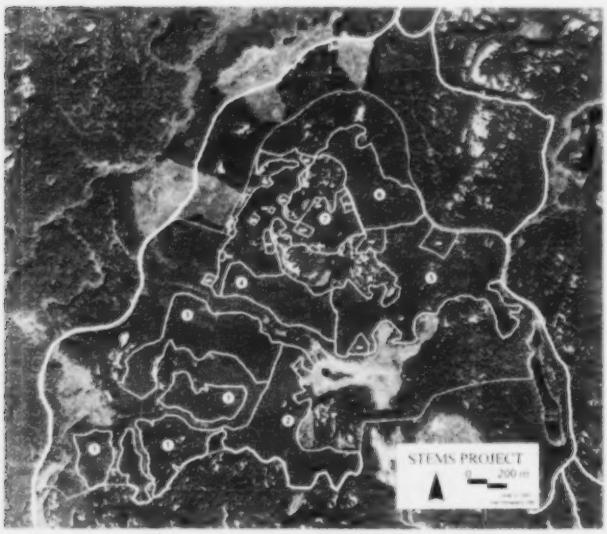

FIGURE A2.1 *Pre-treatment ortho-photo of the STEMS experimental area.*

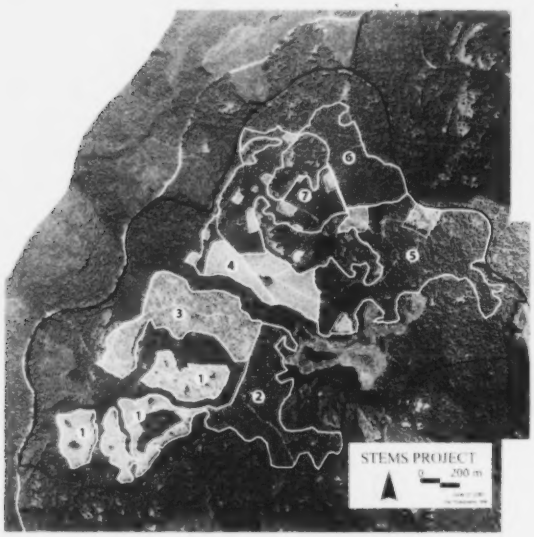

FIGURE A2.2 *Post-treatment ortho-photo of the STEMS experimental area.*

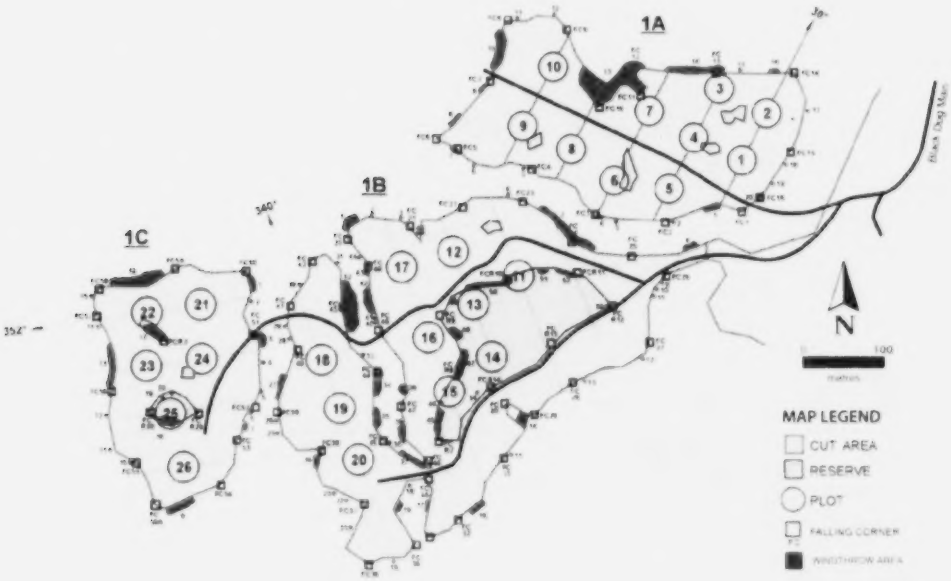

FIGURE A3.1 *Block 1 – Aggregate Retention.*

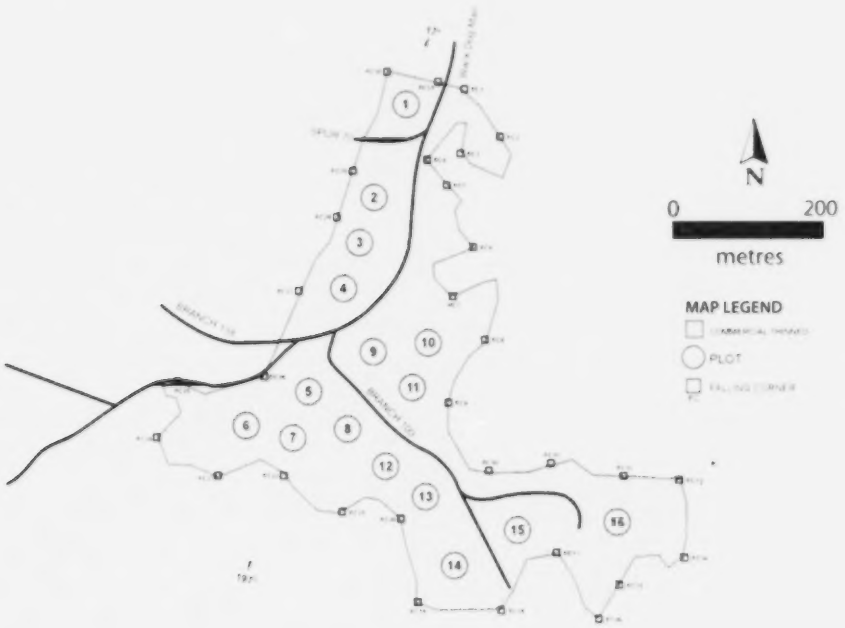

FIGURE A3.2 *Block 2 – Extended Rotation with Commercial Thinning.*

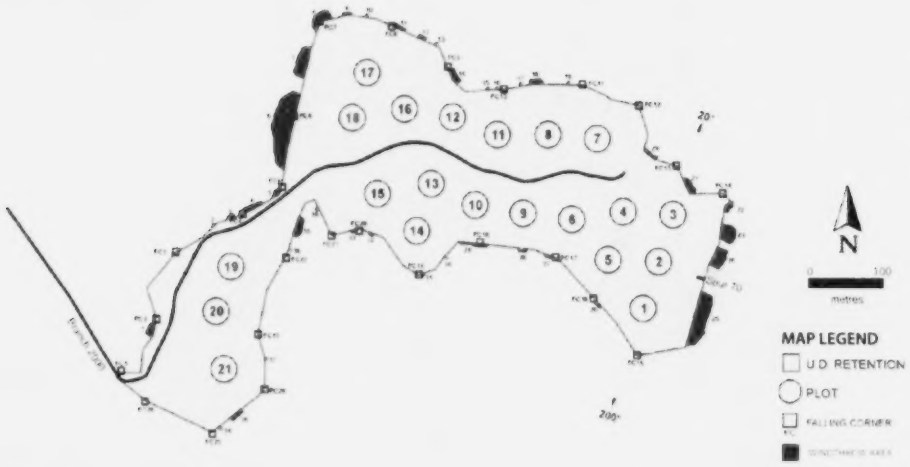

FIGURE A3.3 *Block 3 – Uniform Dispersed Retention.*

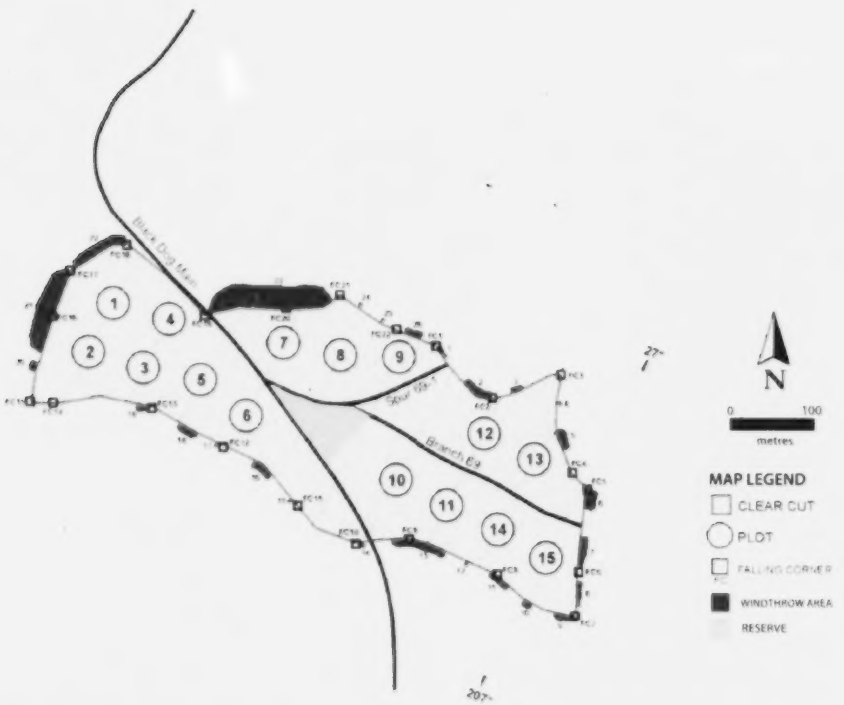

FIGURE A3.4 *Block 4 – Clearcut with Reserves.*

FIGURE A3.5 *Block 5 – Modified Patch Cuts.*

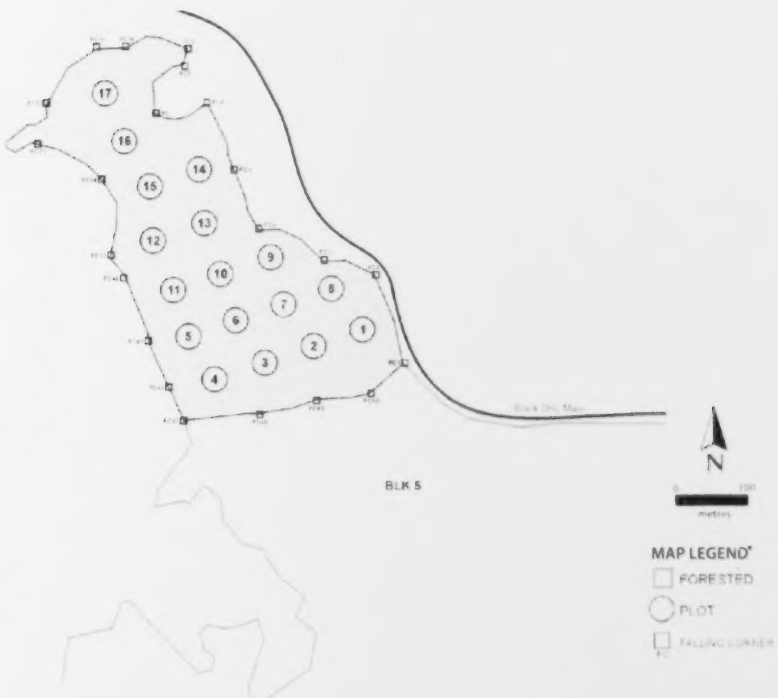

FIGURE A3.6 *Block 6 – Extended Rotation (non-treatment control).*

FIGURE A3.7 *Block 7 – Group Selection.*

Tree Measurements

Pre-treatment plot measurements were done under contract in February/March 2001.

For all treatment units except the clearcut and control (operational blocks 4 and 6), only the central 0.01-ha plot was measured pre-treatment. In the clearcut, the full 0.1-ha plot was measured and, in the control, no measurements were made.

All trees (live or dead) greater than 4.0 cm dbh in all 5.70 m radius circular plots in all operational blocks except the control (Block 6) were tagged sequentially, commencing from north. Temporary, plastic plot tags were stapled at 1.3 m from the point of germination on the high side and always facing the plot centre. All trees greater than 4.0 cm had dbh measured directly above the tag with a steel diameter tape, recorded in millimetres. Species, crown class, tree class, damage, and disease were also recorded. Dead trees were recorded as having dead or broken tops; if a dead tree had a broken top, then an estimated height was recorded.

Heights were measured on a subsample of trees. For each of Douglas-fir, western hemlock, and western redcedar, one tree was randomly selected from each of the three diameter classes (4–15 cm, >15–25 cm, and >25 cm). For other species, such as red alder, yew, and Sitka spruce, one tree was randomly selected across all diameter classes. In addition, the height of the largest-diameter tree was measured. All tree heights were measured to the closest decimetre using a Vertex hypsometer.

Stump Measurements

Data were also collected for all stumps in the six operational blocks and a metal tag was pushed into each stump with an 8-cm nail with the tag facing plot centre. These stump tags were also sequential, commencing from north. Stump measurements, including height high side, species, top inside bark diameter, and bottom (at 30 cm from the bottom) inside bark diameter, were measured with a steel diameter tape and recorded in millimetres. If the stump top was uneven, then the top was visually "folded down" and top measurement taken at this point.

Vegetation Measurements

Percent cover shrub data were also collected for each plot in the six operational blocks. Only the four most prevalent shrubs per plot were recorded. If one of the four most prevalent shrubs was present but percent cover was less than 10%, then the code "TR" (trace) was recorded to indicate that the shrub was not dominating the plot.

In Block 4 (clearcut with reserves), additional full Vegetation Resources Inventory (VRI) data were collected using Allegros and EASYDC electronic application versions of Field Cards 8 and 9. Data were collected for each of the 5.70 m, 12.60 m, and 17.80 m circular plots to full VRI standards. Data for each of the plots were collected separately so it is known in which plot radius the individual tree data occurred. All three radius plots had the first tree recorded from the north position and proceeded clockwise around the entire circle. Care was taken to ensure which plot radius a borderline tree belonged to.

Plot Photographs

Four photos per plot were taken for all plots in all treatment units. All photos were taken from plot centre facing to each of the four cardinal directions. Each photo has an identification card with plot number and cardinal direction in the photo. The plot identification card in the photo indicates the centre of the photo.

Coarse Woody Debris Measurements

Definitions for coarse woody debris (CWD) are based on those from the Vegetation Resource Inventory, as follows:

- CWD is primarily dead woody material in various stages of decomposition, located above the soil; larger than 7.5 cm in diameter (or equivalent cross-section) at the sample transect crossing point; and not self-supporting.
- CWD is fallen trees with green foliage if they are no longer rooted in the ground; large fallen branches and fallen broken tree tops, horizontal or leaning; and recently cut logs, including felled and bucked logs or log decks.
- CWD also includes uprooted (not self-supporting) stumps greater than 7.5 cm in diameter at the crossing point and less than 1.3 m in length; and any exposed dead roots greater than 7.5 cm at the crossing point. Stumps greater than 1.3 m in length are also CWD but considered to be "short logs" (the 1.3 m figure is related to the height definition for intact stumps).
- CWD is not trees and stumps (intact in ground) that are considered self-supporting; live or dead trees (still rooted) that are self-supporting; dead branches still connected to standing trees; exposed roots of self-supporting trees; nor self-supporting stumps or their exposed roots.

All pieces of CWD greater than 7.5 cm in diameter that meet the criteria for sampling are tallied and measured. Fallen or suspended (not self-supporting) dead tree boles, with or without roots attached, that intercept the vertically projected sample line (whether the transect passes above or below the CWD) are measured. CWD may be suspended on nearby live or dead trees, other CWD, stumps, or other terrain features. Unmeasurable suspended CWD is visually estimated at the intercept point.

Pre-treatment CWD was measured on contract as part of a study by Vancouver Forest Region Research Section staff. Three treatment units were sampled for CWD:

- clearcut (15 plots)
- patch (25 plots)
- extended with commercial thinning (15 plots)

Line intersect sampling (LIS) was used to measure the CWD (Marshall et al. 2000; Resources Inventory Committee 2000). A 75 m line transect in a spoke pattern (3- to 25-m lines) was established at the centre of each growth and yield permanent sample plot. The direction of the first 25-m transect was randomly chosen. The other two 25-m transects were established at 120° from each other. All were slope-corrected in the field to 25 m. The B.C. Ministry of Forests provided the compass declination (degrees).

All CWD pieces crossed by the line transect with a top diameter ≥10 cm were measured. Detailed measurements were made for each round or semi-round piece encountered.

Width and height were recorded for pieces with non-round diameters (all pieces with a decay code of 3, 4, or 5). Broken pieces <0.5 m apart were measured as one piece if they were positioned in the same direction. They were coded as reconstructed. Logs that had roots attached were classified as a fallen tree. For branching pieces, length was recorded as per Marshall et al. (2000). Further detail is provided in the attachment. Odd-shaped pieces (e.g., slabs, piles) were measured as per Marshall et al. (2000). Specific data recorded for each type of CWD are found in Appendix 8.

TABLE A4.1 *Soil description by treatment unit (operational block)*

Block	Site series	Humus form	Soil texture	Coarse fragment content (%)	Soil depth (cm)
1a/b	01/03	6 cm moder	SL/LS	40	50
1c	01	4 cm moder 2 cm Ah	SL over SiL	40	80
	05	5 cm moder	SiL	40	80
2	01	6 cm moder	SL/LS	40–70	70
3	01	5 cm moder 2 cm Ah	SL/LS	35–50	75
	05	5–10 cm moder	SiL	50	70
4	01/05	4 cm moder 1–2 cm Ah	SL	25–40	70
5	01	6–10 cm moder	SL	40–55	70
			SL	30–50	70
6	01	10 cm moder	L–SL	40	70
7	01	5–10 cm moder	SL	35–60	60+

TABLE A4.2 *Site series description by treatment unit (operational block)*

Block	Site	BEC site series	Soil moisture regime	Soil nutrient regime	Site index @ 50
1	Variable aspect (N,W,S), flat to 40% slope. Well drained, with minor wet inclusions associated with NCDs*	01 (05, 06)	3	C–D	Fdc = 32 (24–37)
2	Predominantly north aspect, 0–30% slope.	01 (05, 06)	3–4	C (D)	Fdc = 30
3	North to west aspect, 0–35% slope. Lower slopes dominated by SS 05	01/05	3–5	C–D	Fdc = 31 (24–34) Hw = 29
4	Flat to west aspect, 0–12% slope	01 (05)	3 (4)	C	Fdc = 30 (24–37)
5	Variable aspect, 0–40% slope, bedrock outcrops/wet depressions throughout, area of generally poorer sites	01 (03, 06)	3–6	(B) C	Fdc = 28 (24–32)
6	North aspect, 10–30% slope, generally well drained with occasional seepage depressions	01 (05)	3–(4)	C–D	Fdc = 31
7	Variable aspect, 0–40% slopes, well drained with frequent bedrock outcrops	01/05	3–4	C–D	Fdc = 33 (31–34)

* Non-classified drainage (a stream that does not meet the Forest Practices Code definition of a stream).

TABLE A4.3 *Stand description by treatment unit (operational block)*

Block	Species composition	Stems per hectare	Volume (m^3/ha)	Avg. diameter (cm)	Avg. height (m)	Age (2001)
1	F8C1H1	822	458	27.8	30.1	58
2 (leave)	F9C1 (H)	515	350	30.6	30.2	
2 (cut)	F6H4	531	182	23.0	25.9	
3 (cut)	F7H3(CD)	832	426	26.7	29.1	53
3 (leave)	F10	35	45	40.0	32.9	
4	F10(HD)	694	498	31.1	31.5	53
5	F10	967	467	27.5	27.5	58
7	F8H1C1	819	439	28.4	29.0	58

Residual Tree Measurements

B.C. Ministry of Forests Research Branch staff conducted post-treatment plot measurements throughout the fall and winter of 2001/02 as harvesting treatments were completed in each operational block. Plot centres were marked with metal tags indicating the operational block and plot number. From the centre point, a compass and measuring tape were used to establish the location of the three concentric plots in the cardinal directions and distances of 5.7 m, 12.6 m, and 17.8 m. These points were flagged using metal pins with brightly coloured flags. The horizontal distances to these pins were then verified with a laser. The centres of the vegetation/regeneration subplots (located at the cardinal directions of the 17.8 m diameter plot) were marked with white PVC hammered into the ground and labelled with metal tags. The numbering on these subplots was sequential in a clockwise direction starting from the north. The circumference of the outer plot (between the subplot markers) was then measured using a laser and flagged with tape. Trees bordering the plot were marked with a white dot if they were in.

Trees were then tagged and measured by sectors, which were determined by dividing the plot into four along the cardinal directions. Sector 1 was always in the northeast, and numbering was sequential in a clockwise direction. All trees 4 cm or larger were tagged and measured in the 5.7 m plot, trees greater than 15 cm in the 12.6 m plot, and trees greater than 25 cm in the 17.8 m plot. Trees were tagged at breast height, facing plot centre. Small, thin-barked trees had tags attached with barlocks and staples. Dead trees and large, live trees with sufficiently thick bark and snags were tagged with aluminum nails. Dead trees less than 25 cm in diameter or less than 2.5 m in height were ignored. Tree tag numbers started from 1 for each plot.

Trees were measured for dbh and assessed by codes for crown class, tree class, damage, etc. Tree damage by scarring was further assessed using Forest Engineering Research Institute of Canada (FERIC) codes that measured: type of stem damage (surface scuffed or bruised, phloem exposed, wood gouged); cause of stem damage (skidding, falling, windfall, falling tree); extent of damage (length and width); and location of damage (height from ground, circumference of tree at damage, and location in thirds of the tree). Dead trees greater than 25 cm in diameter were assessed for height to break, condition, etc.

After treatment, the position of the plots with respect to canopy openings was specified as *in opening, not in opening,* or *overlapping opening.* If the whole plot was classified as *in opening* or *not in opening,* the same classification was assigned to each quadrant. If the plot was classed as *overlapping,* then each quadrant within the plot was also classed as *in opening, not in opening,* or *overlapping.* Classification was based on vertical projection of crowns of surrounding trees.

All data were recorded electronically on Paravant Field PCs using EASYDC software licensed to the Research Branch of the B.C. Ministry of Forests.

Tree heights were measured after plots had been re-established. Heights were measured under contract by R. White Woods Ltd. in February/March 2002. The site tree, defined as the largest Douglas-fir tree in a 0.01-ha plot, was measured for height if suitable. Suitability was met if the tree was a dominant or co-dominant, not a wolf or veteran or open-grown tree, with a straight stem free of disease, damage, or breakage, free of suppression above

breast height, not repressed and vigorous, and with a full crown. If a suitable site tree could not be found on the inner 5.7 m radius plot, then the 12.6 m radius plot was subdivided into five sectors and a suitable tree was chosen within the newly defined 0.01-ha plot in the northeast sector. If this approach was still unsuccessful, the sectors were sequentially scanned until a suitable tree was found.

All Douglas-fir trees larger than 25 cm in diameter were measured for height and height to base of live crown. Where crown base was uneven, an average was used. Height and height to live crown of species other than Douglas-fir were sub-sampled. For western hemlock and western redcedar, one tree was randomly selected for each of the three diameter classes (4–15 cm, 15.1–25 cm, and >25 cm). For other species, such as red alder, bigleaf maple, Sitka spruce, and yew, one tree was randomly selected across all diameter classes.

Residual Tree Harvest Damage

Tree damage data were collected for each tree with visible damage. Measurements included tree number, species, dbh, type of stem damage (surface bruised, phloem exposed, wood gouged <1 cm deep, wood gouged >1 cm deep, tree stem damaged at the ground), cause of stem damage (yarding, falling, windthrow), width of damage, circumference of the tree at the damage, percentage of the stem damaged, length of damage, lowest point above ground (cm), location of damage (thirds), and damage to root system. The data were summarized in the cost and productivity report (Evans et al. 2003).

Tree Regeneration

Plots for regeneration and vegetation were assessed on a 3.99 m radius (0.005 ha) plot located on each cardinal point 17.8 m from the permanent plot centre (main plot is 0.10 ha). Regeneration and vegetation assessments were done in October 2002 and again in July 2003 using slightly different methodology as described below.

2002 Procedures All plots that had any harvesting activity (all of blocks 1, 2, 3, and 4, and some from blocks 5 and 7) were surveyed. At each subplot, the 3.99 m radius was measured from the subplot centre post and temporarily marked with flagging to ensure accuracy of plot size. Subplot number and plot location information was recorded, including *in opening*, *not in opening*, or *overlapping opening* referring to whether the plot has overtopping canopy cover.

All planted conifers, and also natural ingrowth (broadleaf or conifer) if tallest or second tallest in plot, were tagged and measured. Protocol for measurement was as follows:

- If <1.3 m, then measure height and root collar diameter.
- If ≥1.3 m, then measure diameter at breast height (1.3 m). Also measure root collar diameter until all other seedlings in the plot have exceeded 1.3 m height.

For tallest and second tallest acceptable seedlings,[1] record above dimensions, species, and whether planted or natural (code) in the 0.005-ha plot.

1 An acceptable seedling is one that is free from deformity or injury likely to prevent development into a merchantable tree.

For all other planted seedlings of any size: record above dimensions and species.

Count number of stems of natural ingrowth by species:

- For naturals >50 cm: all stems counted.
- For naturals <50 cm: tally as follows: A = 1, B = 2–5, C = 6–9, D = 10+.

2003 Procedures The second-year survey was more detailed and done on all plots, harvested or undisturbed. This more detailed survey included the following measurements on harvested and undisturbed plots:

1. Within the marked circumference of the subplot, all planted trees were tagged and measured and naturally regenerated trees tallied as described below. Distance from the plot centre to the stem centre of trees situated close to subplot boundaries were accurately measured to determine whether the tree was included as a sample tree.
2. All previously tagged trees were measured and any newly planted trees were tagged and measured. If a planted tree was found in an unharvested plot, it was also tagged and measured. Tags were attached to wire and looped very loosely around the base of the seedling. Species was identified and height measured to the nearest centimetre. Root collar diameter was measured using calipers to the closest millimetre. Seedling health was assessed using appropriate coding (Appendix 7).[2]

For natural regeneration, the following tree size classes were identified:[3]

- germinants (<10 cm tall)
- seedlings (10 cm to 1.3 m height)
- saplings (>1.3 m height but <4 cm dbh)

For each of tree size classes the following procedures were followed:

- species identified
- actual number of stems (except for germinants) counted and recorded
- germinants tallied as follows: A = 1, B = 2–5, C = 6–9, D = 10–19, E = 20–29, etc.

Modal height was measured for the seedling size class only. Only the tallest and second tallest acceptable seedlings[4] in the subplot were tagged and measured. Tags were attached to wire and looped loosely around the base of the seedling. Species was identified and the seedling measured for height to the nearest centimetre. Root collar diameter was measured using calipers to the closest millimetre. Seedling health was assessed using appropriate coding[5] (see Appendix 7).

Photographs were taken of each plot taken from the south boundary of the subplot facing towards the subplot centre post. The corresponding plot number and photo number were recorded.

2 Based on coding established by the Expert Committee on Weeds.
3 Tree size classes are from the *Stocking and Free Growing Survey Procedures Manual*, May 2002, Forest Practices Branch, B.C. Ministry of Forests.
4 An acceptable seedling is one that is free from deformity or injury likely to prevent development into a merchantable tree.
5 Based on coding established by the Expert Committee on Weeds.

Vegetation Assessments

Vegetation assessments were done using the same plots as for regeneration, a 3.99 m radius (0.005 ha) plot located 17.8 m from the permanent plot centre at each cardinal point. Vegetation assessments were done in October 2002 for all plots that had any harvesting activity (all of blocks 1, 2, 3, and 4, and some from blocks 5 and 7) and in July 2003 for all plots. The procedures were slightly different for each survey.

In October 2002, plot percent cover and modal height were recorded for all species having greater than 1% cover. In July 2003, a more detailed vegetation assessment was done on all plots. Vegetation assessments were based on a modification of the Vegetation Resource Inventory (VRI) Field Cards 14 and 15 with a plot size of 3.99 m (50 m^2) (see http://srmwww.gov.bc.ca/risc/pubs/teveg/vri_ground_sampling2k3/appen_vri_ground2k3.pdf). The work was split so that Research Branch staff assessed all harvested plots and certified VRI contractors assessed all undisturbed plots. This was done because there were too many plots for Research Branch staff to complete within an acceptable timeframe, and not enough money to pay contractors to survey all the plots. However, potential for confounding was thought to be acceptable because the disturbed and undisturbed plots must be analyzed separately anyway. See Appendix 8 for vegetation coding.

Samples were identified to the species level for all trees, shrubs, and herbs, but not for grasses, sedges, rushes, and bryoids. For species with less than 1% cover, we indicated that it was trace.

The following data were collected:

1. Overall percentage cover of:
   - all vegetation
   - all trees and shrubs in layer A (>10 m)
   - all trees and shrubs in layer B1 (2–10 m)
   - all trees and shrubs in layer B2 (<2 m)
   - all herbs, layer C
   - all bryoids, layer D (if there was more than just mosses, it was noted in comments)
2. Percentage cover of trees and shrubs by genus and species in the A layer (>10 m)
3. Percentage cover and modal height by genus and species of:
   - trees and shrubs in the B1 and B2 layers
   - herbs in the C layer (for grasses, sedges, and rushes, Family level was acceptable)

Coarse Woody Debris

Post-treatment sampling of CWD was done in February 2003. The sampling was done on the same three treatment units using the same transects used for the pre-treatment survey (clearcut with reserves, extended rotation with commercial thinning, and modified patch cuts). In addition to the data collected as described for the pre-treatment CWD, the sampling was further complicated by piles of machine-piled debris and exposed root wads in stumped areas. In stumped areas, Marshall and Davis (2002, p. 5) recommended separating the root wad and the tree bole as follows:

> "In the case of a windfall with attached roots, consider the bole and root wad as two measurement groups. This will improve sampling efficiency and accuracy by removing uncertainty about how to tackle a complex situation. In this document, only bole meas-

urements are considered. Root wads may be sampled using either LIS or some other technique, with appropriate measurements taken on each sampled root wad to estimate the attributes of interest (e.g., volume/ha, biomass/ha).

"The suggested definitions are as follows:

- Root wad = the volume of wood below the point of germination (POG) or high side, whichever is higher.
- CWD or bole wood = the portion of the tree bole between POG or high side (whichever is higher) and the small end of the piece.

"If the transect line crosses the centre axis of the tree bole, then record length from either the high side or POG (whichever is higher) to the minimum small-end diameter. If the transect line crosses only the centre axis of the root wad, then no measurement is recorded unless the root wad is being sampled. If both the root wad and bole are crossed by the transect, then each is recorded as a separate entity. If a piece is partially broken at the butt and some roots are still attached, none of the root wad should be used to "fill in" the missing part of the bole.

"The rationale is that for ease of sampling, tree boles and root wads are defined as separate groups. Due to their different shapes, different measurements and possibly different sampling strategies are required."

While Marshall and Davis (2002) recommend separating the tree bole from the root wad, they do not give details for sampling root wads. This procedure would be complicated, laborious, and time-consuming if one wished to estimate the volume of material in an exposed root wad. In a similar way that branchwood on standing trees is not described or measured, the detailed measurement of root material would serve no useful purpose within this study.

For ease of application, combining the VRI approach with the recommendations of Marshall and Davis, the following procedure was used:

1. Fresh blowdown is sampled if the downed trees are no longer rooted and therefore are assumed to be either dying or dead. Some foliage will be retained for various lengths of time, depending on the species (especially true firs). This may give the appearance that the downed tree is still alive.
2. Large exposed roots of overturned stumps should be sampled as CWD, if large enough in diameter at the transect crossing. The length should be taken to the POG, the division point between the bole wood and the root wad.
3. If significant piles of overturned, uprooted stumps exist, they should be sampled using a separate procedure (not the line intersect sampling) to estimate the dimensions of the stumps (bole wood only), above the POG.

The measurement and codes used are shown in Appendix 6.

Subsequent periodic sampling of CWD to determine state of decay and recruitment will be done during plot remeasurement if funding is sufficient. Future wildlife studies can be done to determine habitat suitability over time, as a separate study.

Soil Disturbance

Soil disturbance was surveyed under contract as described in the "Survey methods for soil disturbance and forest floor displacement" and "Transect method for areas 10 hectares and smaller" sections (pp. 29–37) of the *Soil Conservation Surveys Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Land and Parks 1997).

In the STEMS experiment, 14 strata were identified on the basis of harvesting treatment (six), site series (two), and site preparation (stumped and not stumped), as shown in Table 13 of the Results section).

The starting and ending location of each transect line used in the survey of each stratum were field marked with either "start" or "end," transect distinguishing identification number or letter, and bearing in azimuth. For each stratum surveyed, soil disturbance summary information was recorded as listed in field card FS 889 HSP 96/10.

The contractor recorded the approximate location of strata and transect lines (field information developed in previous subsections) by sketching a site map on the back of field card FS 889 HSP 96/10. The site map included approximate location of north arrow, strata unit boundary in relation to identifying feature (e.g., road or major stream), prevailing yarding direction, baseline location (if used), and starting and ending point of each numbered transect line.

Soil disturbance and forest floor displacement categories were recorded on Transect Survey Field Card FS 885 HSP 96/8. Soil disturbance survey summary information was calculated on field card Small Area Survey Calculation Card FS 897 HSP 96/9. Photographs were taken of representative examples of soil disturbance categories found in each stratum.

For each stratification unit surveyed, the contractor briefly described the site, survey results, the most common soil disturbance categories observed, and impressions of the regeneration potential for the sites compared with the adjacent area.

All survey site write-ups, site maps, transect survey field cards, and photographs (identifying the associated soil disturbance category) were submitted. The work was done in January and February 2003. The data are summarized in Table 13 and in Evans et al. (2003).

Windthrow Surveys

For those plots that were partially cut (23 plots in Block 1, 21 in Block 3, five in Block 5, and nine in Block 7), a 100% tree tally was conducted to verify the tree status. For those plots that were not partially cut, a visual sweep of the entire plot was done to find trees that had been windthrown or broken, or were leaning. The following information was collected:

- the classical topex for each plot: the sum of the positive angle to skyline in eight cardinal directions
- tree tag number
- status of tree (SL=Standing Live; SD=Standing Dead (snags including those with broken tops); SB=Standing Broken (new wind damaged); UR=Uprooted (new wind damaged); LL=Leaning Live (new wind damaged); LD=Leaning Dead.
- height and height to base of live crown if these measurements were not previously measured (i.e., all Fd trees >25 cm have been measured)
- bearing in direction of fall for UR trees and direction of lean and break for LL trees
- height to break if broken for standing broken only

- angle of lean if not downed and if leaning >5° because of wind or contact with windthrown tree
- if the tree was windthrown or knocked over by another falling tree (look for arrangement and scarring) and tree number of tree that knocked it over
- average root depth of one representative tree from point of germination to bottom of root plate and any evidence of root decay

Along operational block edges, especially blocks 1, 3, 4, 5, and 7, any windthrow along uncut edges was measured as follows:

- location of affected edge, relative to blazed falling corners
- length of edge that has been affected (windthrown)
- depth of windthrow from the harvested boundary into the uncut forest (distance from the boundary edge to closest standing trees outside the windthrown edge from points taken every 10 or 20 m along the edge, relative to blazed corners). The mean depth of damage was calculated for each section of windthrown boundary.
- estimated direction of fall
- estimated number of windthrown trees >25 cm
- estimated number of windthrown trees <25 cm

Downed trees were marked using spray paint. The overall location of windthrown areas and boundaries, and direction of fall were mapped.

All coarse woody debris (CWD) pieces crossed by the line transect with a top diameter ≥10 cm was measured. For each round or semi-round piece encountered, the following data were recorded:

1. **Treatment Unit:**
2. **Plot #:**
3. **Transect #:** a, b, or c
4. **Direction:** Direction of transect (in degrees)
5. **Slope:** Slope of transect (%)
6. **Transect Length:** Length of transect (25 m, slope corrected)
7. **Piece Number:** Piece number from beginning of transect
8. **Piece Code:** Branch, Log, Fallen tree (with recognizable roots attached)
9. **Species:** G&Y species codes
10. **Angle:** Vertical angle of piece (in degrees)
11. **Orientation:** Horizontal angle of piece (in degrees)
12. **Shape:** L = Loaf, S = Slab, R = Round, O = Oval
13. **Segmented:** Number of piece segments (e.g., S1, S2, S3)
14. **Reconstructed:** Is the piece reconstructed? (yes/no)
15. **Transect IBW:** Transect inside bark width (cm)
16. **Transect IBH:** Transect inside bark height (cm)
17. **Transect Bark:** Transect bark thickness (cm)
18. **Bark Condition:** L = Loose, F = Firm, N = None
19. **Length One:** Piece length left of transect (m)
20. **Length Two:** Piece length right of transect (m)
21. **IB Diameter:** 5 m up log from a butt that is >100 cm in diameter
22. **Butt IBW:** Butt inside bark width (cm)
23. **Butt IBH:** Butt inside bark height (cm)
24. **Butt Bark:** Butt bark thickness (cm)
25. **Butt Cut:** N = New, O = Old, L = Natural
26. **Top IBW:** Top inside bark width (cm)
27. **Top IBH:** Top inside bark height (cm)
28. **Top Bark:** Top bark thickness (cm)
29. **Top Cut:** N = New, O = Old, L = Natural
30. **Ecological Code:** 1 = Live or recently dead / bark and twigs <3 cm intact, 2 = Dead / bark loose and no twigs <3 cm intact, 3 = Rotting but still round / little bark and few branches intact, 4 = Advanced decay / shape collapsing and no bark or branches intact, 5 = Final decay stage before becoming soil / oval (see figures attached)
31. **Dominant Grade:** (e.g., X, Y, Z) (optional)
32. **Rot:** S = Sap, H = Heart, N = None
33. **Heart Rot / Hole dimensions:** Height (cm); Width (cm); Estimated length if known
34. **Bark Code:** 1 = 100% present, 2 = 100–75% present, 3 = 75–50% present, 4 = 50–25% present, 5 = <25% present
35. **Charcoal:** Charcoal on piece? (yes/no)
36. **Comments:**

Width and height were recorded for pieces with non-round diameters (all pieces with a decay code of 3, 4, or 5). Broken pieces <0.5 m apart were meas-

ured as one piece if they were positioned in the same direction. They were coded as reconstructed. Logs that had roots attached were classified as a fallen tree. For branching pieces, length was recorded as per Marshall et al. (2000). Further detail is provided in the attachment.

Odd-shaped pieces (e.g., slabs, piles) were measured as per Marshall et al. (2000). Specific data recorded included:

37. **Treatment Unit:**
38. **Plot #:**
39. **Transect #:** a, b, or c
40. **Direction:** Direction of transect (in degrees)
41. **Slope:** Slope of transect (%)
42. **Transect Length:** Length of transect (slope corrected) (m) (i.e., 25 m)
43. **Piece Number:** Piece number from beginning of transect
44. **Piece Code:** P (Pile), S (Slab), etc.
45. **Species:** use G&Y species codes
46. **No. of Pieces:** Number of pieces
47. **Reconstructed:** Is the piece reconstructed? (yes/no)
48. **Width of Rectangle:** Width along transect (cm)
49. **Height of Rectangle:** Estimated height corresponding to transect width (in cm)
50. **Ecological Code:** 1 = Live or recently dead / bark and twigs <3 cm intact, 2 = Dead / bark loose and no twigs <3 cm intact, 3 = Rotting but still round / little bark and few branches intact, 4 = Advanced decay / shape collapsing and no bark or branches intact, 5 = Final decay stage before becoming soil / oval (see figures attached)
51. **Dominant Grade:** (e.g., X, Y, Z) (optional)
52. **Comments:**

INSTAL: Installation number

BLOCK: Treatment unit number

PLOT: Plot number

SUBPLOT: Subplot number
1=N, 2=E, 3=S, 4=W

SELECT: Trees selected for height measurements
TT=Tallest Tree, ST=Second tallest Tree, PT=other Planted Tree, RP= Replacement Tree

ORIGIN: Planted or natural
PL=Planted, NA=Natural

S_TYPE: Shade environment (small gap<1.5 x height of Dominant tree)
FS =Forest Shade, SSG=South side of Small Gap, NSG=North side of Small Gap, MSG=Middle of Small Gap, SLG=South side of Large Gap, NLF=in forest North of Large Gap, OP=north of large and small gaps

SPECIES: Tree species identification
Fd=Douglas-fir, Cw=western redcedar, Hw=western hemlock, Bg=grand fir, Pw=white pine, Lw=western larch, Dr=red alder, Ep=paper birch, Act=black cottonwood, Mb=bigleaf maple

TREENO: Tree tag number

GLD: Diameter at ground (mm)

HEIGHT: Tree height in 2003 (cm)

HT_02: Tree height in 2002 (cm)

Dbh: Diameter at breast height (mm)

SURCODE: Survival coding
0=alive, 1=dead, 2=pulled out, 3=missing, 4=poor vigour, 5=good vigour

LDRCODE: Leader code
H=Healthy, C=Curled, F=Forked, M=Multiple leader, B=Browsed, T=dead Terminal bud, S=Snapped or broken, A=Absent, Z=stunted needles, O=Other (specify)

LDRDAM: Leader damage code
A=none, M=Mechanical, S=falling Slash (human), X=falling debris, N=snow press, V=vegetation press, E=climate-frost, W=climate-drought, R=Rodents, B=Big game, F=Fire, I=Insects, D=Disease, O=Other (specify), U=Unknown.

FOLCODE: Foliage code
H=Healthy, Y=chlorotic, M=Mottled, N=Necrotic, A=needles Absent or defoliated, B=Browsed, D=Dead buds on laterals, L=Lammas growth, O=Other (specify)

FOLDAM: Foliage damage code

A=none, M=Mechanical, S=falling Slash (human), X=falling debris, E=climate-frost, N=snow press, V=Vegetation press, W=climate-drought, R=Rodents, B=Big game, F=Fire, I=Insects, D=Disease, O=Other (specify), U=Uknown

REM02: Remarks made in 2002

DATE: Date of measurement

INSTAL: Installation number

BLOCK: Treatment unit number

PLOT: Plot number

SUBPLOT: Subplot number (3.99m radius)
1=N, 2=E 3=S, 4=W

CANOPY: Canopy Influence Code
1=in opening, 2=overlapping, 3=not in opening

REGEN: Regeneration Code
GE=Germinant <10 cm, SD=Seedling >10 cm, SA=Sapling >1.3 m and <4 cm dbh, PL=Planted

LAYER: Layer Code (put remark for lichens)
A=>10 m trees and shrubs, B1=2–10 m trees and shrubs, B2=<2 m trees and shrubs, C=herbs, D=bryoids

SPECIES: Species Code
Use vegshrub.txt

PERCCOV: % Cover
1 to 100% (<1%=0.1)

MODALHT: Modal Height (cm)

TALLY: Tally by species of germinants, seedlings or saplings
A=1, B=2–5, C=6–9, D=10–19, E=20–29, F=30–39, G=40–49, H=50+

DENSITY: Count by species of seedlings >10 cm and <130 cm

REMARKS: Remarks

DATE: Date of measurement

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